M 2023

The digitalisation of quality-related data in an Automotive Engineering Services Company

Margarida Inês de Sousa Barbosa

MASTER'S THESIS SUBMMITED TO

FACULDADE DE ENGENHARIA DA UNIVERSIDADE DO PORTO

UNIVERSITY SUPERVISOR

PR. DR. LAURA RIBEIRO

CES SUPERVISOR

ENG. ANDRÉ SILVA RIBEIRO

U.PORTO
FEUP FACULDADE DE ENGENHARIA
UNIVERSIDADE DO PORTO

CANDIDATO Margarida Inês de Sousa Barbosa	*Código* 201806328
TÍTULO The digitalisation of quality-related data in an Automotive Engineering Services Company	
DATA	___de setembro de 2023
LOCAL	Faculdade de Engenharia da Universidade do Porto – Sala_____-___:_h

JÚRI	*Presidente*	DEMM/FEUP
	Arguente	DEM/FEUP
	Orientadora Professora Doutora Laura Maria Melo Ribeiro	DEMM/FEUP

Resumo

Esta tese de mestrado explora a incorporação de princípios da Indústria 4.0 no sistema de gestão da qualidade (SGQ) de uma empresa de serviços de engenharia do setor automóvel. Com o objetivo de promover a tomada de decisões baseada em dados reais, o estudo visa diminuir a lacuna entre os conceitos teóricos e a implementação de práticas da Indústria 4.0.

O estudo inicia-se com a análise do SGQ atual da empresa CES (Continental Engineering Services), avaliando-se o cumprimento das normas da indústria. O compromisso da CES com a qualidade baseia-se no seu SGQ, composto por elementos essenciais como gestão de recursos, desenvolvimento de produtos, análise e melhoria contínua.

O estudo realizado investigou a utilização do Microsoft Power BI na criação de relatórios detalhados e dashboards da qualidade, permitindo à CES monitorizar os indicadores de desempenho (key performance indicators (KPIs) em várias áreas. A característica dinâmica e interativa dos relatórios em Power BI melhora a eficácia e incentiva a tomada de decisões baseada em dados reais. Este trabalho aprofunda a análise de dados, utilizando a metodologia CRISP-DM para a sua exploração sistemática. Mostra como métodos estatísticos e de análise exploratória ajudam a fornecer uma compreensão mais profunda do desempenho ao nível dos projetos.

As iniciativas para melhorar o desempenho em termos de gestão da qualidade são descritas, sendo uma delas o desenvolvimento de relatórios em Power BI e a análise de correlação de indicadores da qualidade relativos à execução de projetos. As melhores práticas para relatórios de qualidade são sugeridas, incluindo automatização e melhoria da relação de dados, para insights em tempo real. Além disso, enfatiza-se a manutenibilidade de relatórios e ferramentas como um componente importante da gestão da qualidade. A tomada de decisões eficaz requer relatórios de fácil utilização com descrições concisas e apresentação otimizada de dados.

O estudo destaca também como os princípios da Indústria 4.0 transformaram a gestão da qualidade na empresa. São mencionadas sugestões para trabalho futuro, incluindo a implementação de sistemas de alerta proativos, simplificação de relatórios de dados e análise de lacunas nas métricas de qualidade. Os resultados obtidos abrem oportunidades para maior criatividade e adaptabilidade num ambiente tecnológico em constante mudança, melhorando, em última análise, o controlo da qualidade em empresas de serviços de engenharia automóvel.

Palavras-Chave

Qualidade; Sistema de Gestão da Qualidade; Insústria Automóvel; Indústria 4.0; Análise de dados; Inteligência de Negócios (BI); PowerBI; Indicadores Chave de Desempenho (KPIs); Automação.

Abstract

This master's thesis explores the incorporation of Industry 4.0 principles into the quality management system (QMS) of an engineering services company in the automotive sector. With the aim of promoting decision-making based on real data, the study aims to bridge the gap between theoretical concepts and the implementation of Industry 4.0 practices.

The study begins by analysing the current QMS of the company CES (Continental Engineering Services), assessing compliance with industry standards. CES's commitment to quality is based on its QMS, which is made up of essential elements such as resource management, product development, analysis, and continuous improvement.

The study investigated the use of Microsoft Power BI to create detailed reports and quality dashboards, enabling CES to monitor key performance indicators (KPIs) in various areas. The dynamic and interactive nature of Power BI reports improves efficiency and encourages decision-making based on real data. This paper delves into data analysis, using the CRISP-DM methodology for its systematic exploration. It shows how statistical and exploratory analysis methods help provide a deeper understanding of project-level performance.

Initiatives to improve performance in terms of quality management are described, one of which is the development of reports in Power BI and the correlation analysis of quality indicators relating to project execution. Best practices for quality reporting are suggested, including automation and improved data linkage for real-time insights. In addition, the maintainability of reports and tools is emphasized as an important component of quality management. Effective decision-making requires user-friendly reports with concise descriptions and optimised data presentation.

The study also highlights how the principles of Industry 4.0 have transformed quality management in the company. Suggestions for future work are mentioned, including implementing proactive alert systems, simplifying data reporting and analysing gaps in quality metrics. The results obtained open up opportunities for greater creativity and adaptability in an ever-changing technological environment, ultimately improving quality control in automotive engineering service companies.

Key-Words

Quality; Quality Management System; Automotive Industry; Industry 4.0; Data Analysis; Business Intelligence (BI); Power BI; Key Performance Indicators (KPIs); Automation.

Agradecimentos

Ao concluir esta importante etapa da minha vida académica, sinto uma enorme gratidão que é difícil expressar em palavras. Este mestrado tornou-se uma jornada repleta de obstáculos, desenvolvimento pessoal e, acima de tudo, apoio valioso de pessoas incríveis.

Aos meus pais, que foram sempre fonte inabalável de amor, inspiração e apoio ao longo da minha vida. Obrigado por estarem sempre ao meu lado desde os primeiros passos até esta conquista académica. Um reconhecimento à minha irmã, Bárbara, pela interminável fonte de paciência e dedicação comigo.

Além disso, quero expressar minha gratidão ao meu padrinho, Humberto Luís, pela companhia e conselhos, e a toda a minha família pelo carinho e acompanhamento diário do meu crescimento.

Na FEUP, onde vivi alguns dos momentos mais desafiantes e gratificantes de minha vida, quero expressar a minha gratidão a todos que partilharam esta atribulada experiência comigo. Em particular a amizade e o apoio de Sofia Alves foram inestimáveis, assim como as suas palavras de encorajamento nos momentos difíceis e memórias alegres que tornaram esta viagem inesquecível.

Aos meus amigos de Penafiel, aqueles que têm sido os meus pilares há muitos anos, quero agradecer pelas suas mensagens de incentivo e conversas sinceras constantes, pelo convívio e companheirismo em todos os momentos.

A professora Laura Ribeiro, pela disponibilidade e acompanhamento desde a desafiante proposta para a orientação deste trabalho, assim como o apoio e incentivo que proporcionou no meu percurso académico.

A toda a equipa docente do departamento e em especial ao técnico Sr. José Ramiro Soares pela sua disponibilidade, ajuda prestada e acompanhamento ao longo dos cinco anos que partilhamos.

Gostaria ainda de agradecer ao Eng.º André Silva Ribeiro, Quality Manager da Continental Engineering Services (CES), pela oportunidade e disponibilidade. À notável equipa da CES, à Paula e ao Marcelo, pelo acolhimento caloroso, pela amizade estabelecida e por tornarem possível a criação de amizades no local de trabalho.

Enquanto abraço o futuro com expectativa, levarei comigo as lições e amizades preciosas que adquiri ao longo deste caminho. Espero que a nossa ligação continue a florescer.

Margarida Inês de Sousa Barbosa

"I am not afraid of storms,
for I am learning how to sail my ship."

Little Women

Contents

1. Introduction 1

1.1 The Company 4

1.2 Problem Description 5

1.3 Objectives 6

1.4 Thesis Structure 6

2. Literature Revision 8

2.1 Quality Management Systems in the Automotive Industry 8

2.1.1 Standardisation 9

2.1.1.1 IATF 16949 - Automotive Quality Management Systems 9

2.1.1.2 ASPICE - Automotive Software Process Improvement Capability dEtermination 11

2.1.2 Quality Practices – Frameworks and Tools 13

2.1.2.1 Project Tracking Software 15

2.1.2.2 Web Collaboration Software 16

2.2 Digitalisation of Quality 17

2.2.1 Quality Metrics 18

2.2.2 Big Data Analytics 19

2.2.3 Business Intelligence 21

2.2.3.1 ETL – Extract, Transform, and Load. 23

2.2.3.2 Data Warehouse 24

3. Case Study 25

3.1 Quality Management System at CES 25

3.1.1 Current Practices and Tools 26

3.1.2 Quality Reporting 29
3.1.2.1 Reporting Key Performance Indicators 32
3.1.2.2 Dashboards 32
3.1.3 Data Analysis 36
4. Approaches for Improvement 38
4.1 Reporting Key Performance Indicators and Monitoring 38
4.1.1 Creation of a QMS Category Report 39
4.1.2 Correlation Analysis of KPIs 41
4.2 Reports and Tools Automation 45
4.3 Reports and Tools Maintenance 46
5. Conclusions 48
5.1 Analysis and Evaluation of the Project 48
5.2 Future Work 48
6. Appendix 55
Appendix 1 – Report Pages from CES Quality Power BI Dashboard 55

List of Figures

Figure 1: Industrial Revolution Stages Flowchart (Haokip 2021). 2

Figure 2: Industry 4.0 framework and contributing technologies (PwC 2016). 3

Figure 3: Continental Engineering Services (CES) service portfolio (Continental Engineering Services 2023). 5

Figure 4: IATF 16949 Five Core Documentation Tools (Plexus International 2023). 10

Figure 5: ASPICE capability dimension overview (Noureldin et al. 2022). 12

Figure 6: Kanban Board Configuration (Mircea 2019). 15

Figure 7: Graphical representation of the relationship between data analytics and insights (Sansom 2022). 20

Figure 8: BI Architecture (Ong, Siew, and Wong 2011). 22

Figure 9: Continental Process Map showing the ten binding process areas. 26

Figure 10: JIRA Software platform screenshot 28

Figure 11: CES Power BI dashboard flow structure. 31

Figure 12: Process steps to build a dashboard (Kintz, Kochanowski, and Koetter 2017). 34

Figure 13: Pen and Paper example of ideation takeaway. 35

Figure 14: CRISP-DM Methodology Framework. 36

Figure 15: CES Customer Satisfaction History Report. 40

Figure 16: FPY Status Statistical Distribution Power BI Report. 43

Figure 17: PQSR Status Statistical Distribution Power BI Report. 44

CHAPTER 1

INTRODUCTION

The automotive sector stands as a dynamic and ever-evolving capital-intensive industry (Dieguez et al. 2020). Its strength leverages various activities of the worldwide economy, ranging from the early stages of development and manufacturing of vehicles to its sales and aftermarket support. This industry is recognised for its innovation and influence on mobility, constantly adapting to new technological developments to improve performance, sustainability, and safety (Popkova et al. 2018).

The sector has experienced several significant revolutions, each accompanied by major discoveries and technological advancements, and each stage is displayed in Figure 1 (Valladares Montemayor and Chanda 2023). The first industrial revolution began in the 18th century with steam engines as a novel power source. The whole manufacturing process was revolutionised through the second industrial period, as electricity and assembly lines were discovered (Papulová, Gažová, and Šufliarský 2022). For the third industrial revolution, computer technologies, such as Programmable Logic Controllers (PLCs), became widely accessible. As the fourth industrial revolution occurred, the industry was introduced to advanced intelligent processes incorporated with the Internet of Things (IoT), Cloud Technology, and Big Data (Delloite Insights 2020).

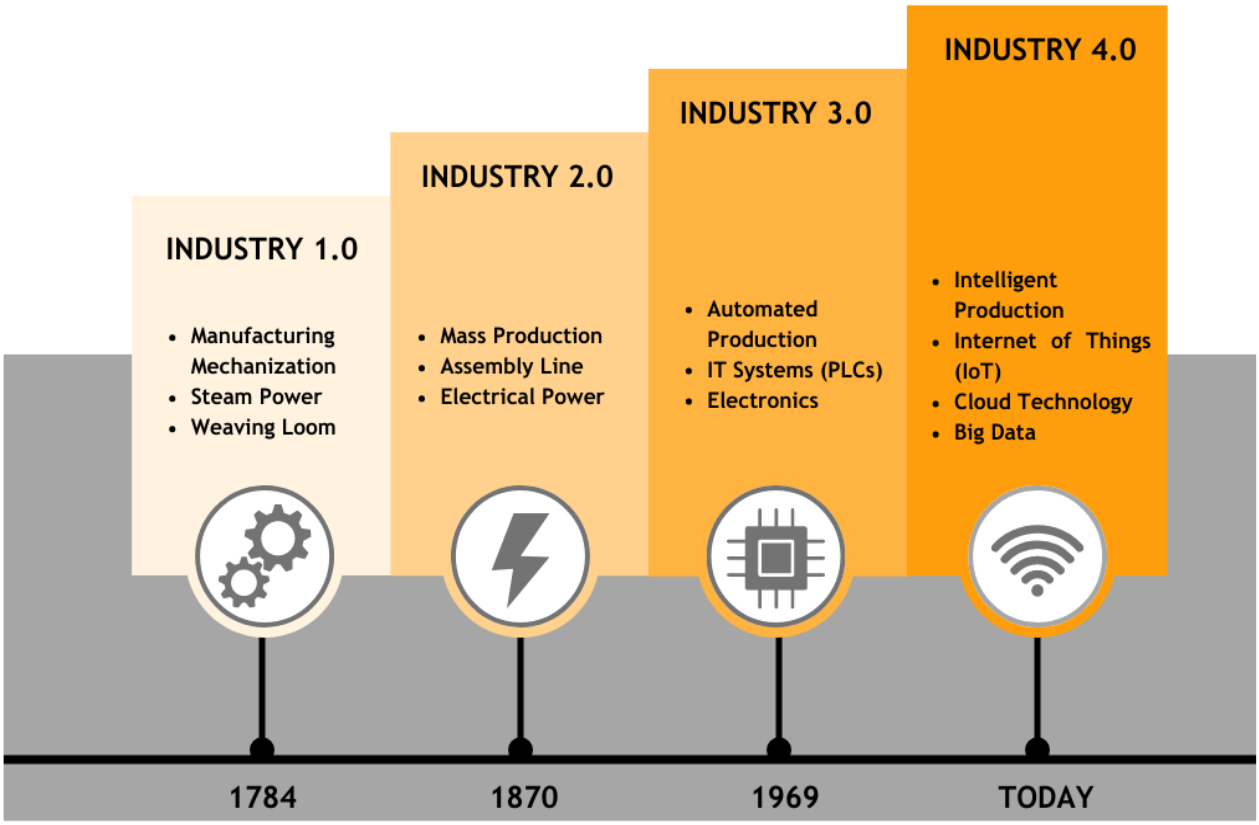


Figure 1: Industrial Revolution Stages Flowchart (Haokip 2021).

Companies are embracing Industry 4.0 solutions in line with the pursuit of autonomous vehicles (Burkacky et al. 2019). The delicate balance usage of conventional manufacturing practices combined with the integration of cutting-edge technologies, such as Artificial Intelligence (AI), Machine Learning (ML), and Autonomous Systems (AS), supports the design, engineering, and testing of next-generation vehicles (PwC 2016). Figure 2 provides an overview of the framework and its contributing technologies in Industry 4.0.

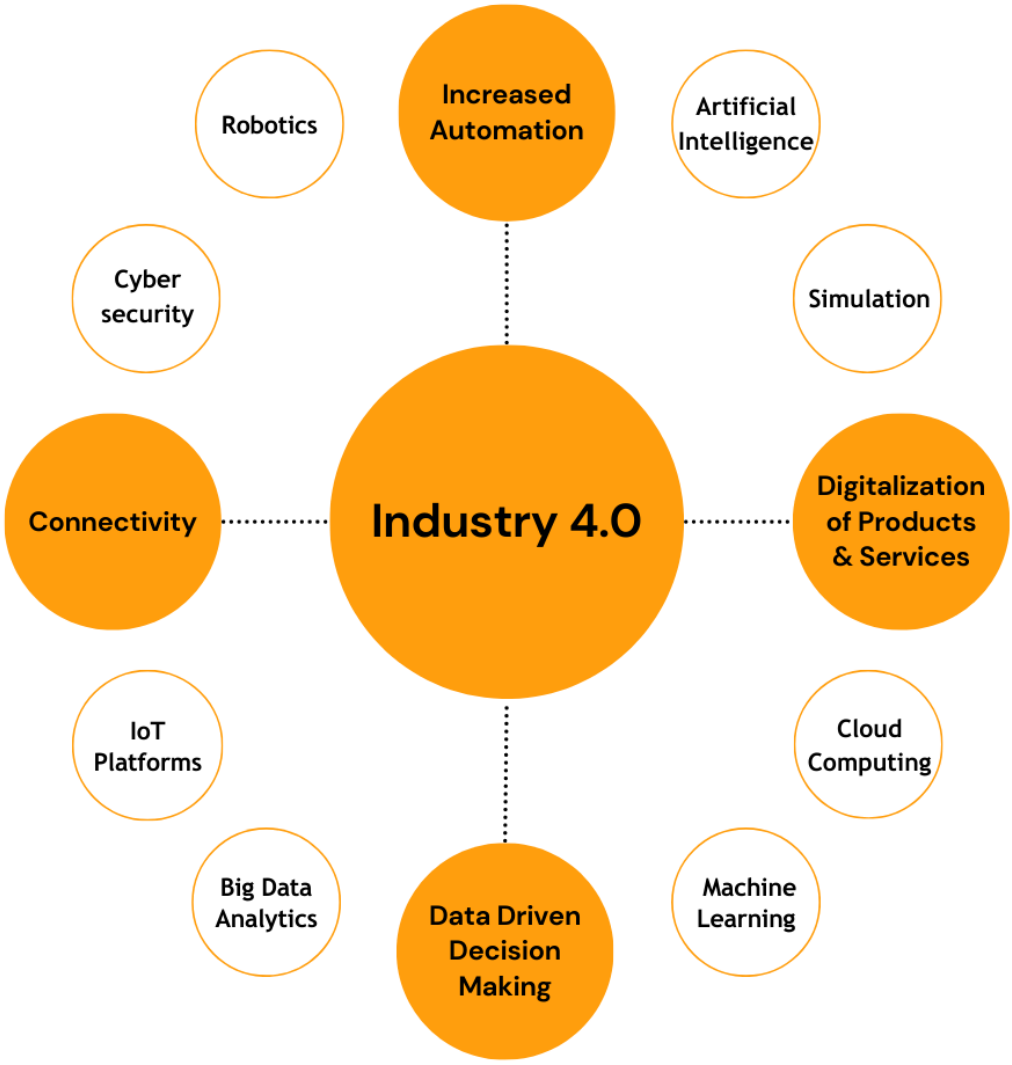


Figure 2: Industry 4.0 framework and contributing technologies (PwC 2016).

An essential step toward innovation and improvements in the automotive sector is the digitalisation and integration of automation in the Quality Management System (QMS) (Singh et al. 2022). Companies can improve quality, save costs, and gain a competitive edge in the global market, as the adoption of this synergetic connection is essential and represents a crucial milestone.

The work described throughout this thesis document inserts itself in the context of Industry 4.0 as it implements the technologies and frameworks that arise with this revolution, driving performance improvements in quality management. Its primary focus is to address the digitalisation of data and information relevant within the Quality

Management System. This encompasses data related to customer satisfaction, supplier performance, project quality performance, and more. This integration through advanced technologies improves the quality management process's efficiency, accuracy and effectiveness.

The methodologies, technologies, and results related to the digitalisation and integration of quality-related information and data within the framework of Industry 4.0 will be covered in more detail in the following sections of this thesis.

1.1 THE COMPANY

The Continental Group is a recognised automotive company with a distinguished history spanning over a century. That began as "Continental-Caoutchouc-und gutta-percha Compagnie" in Germany and initially specialised in producing components for bicycles and carriages. However, in 1898, Continental ventured into the production of tires for light cars and commercial vehicles, which led to its significant success (Continental 2023).

Its business grew over time, leading to the opening of research facilities and an extensive manufacturing network across multiple countries. The group is committed to providing cutting-edge technologies and innovative solutions and encouraging corporate social responsibility and sustainability practices (Continental 2023).

Continental Engineering Services (CES) is one of Continental Group's subsidiaries active in Portugal, specialising in engineering services for the automotive industry while still serving many other sectors, including rail, shipping, agriculture, aerospace, and medicine (Continental Engineering Services 2023).

Since 2006, CES has located itself in Europe, North America, China, and Japan, providing innovative technological solutions by adapting high-volume technologies for small series, niche, two-wheeled, special vehicles, and industrial uses.

The company is a leading engineering global partner for automotive and industrial clients, thanks to its broad service portfolio, available in Figure 3, which includes software and hardware development, product supply, integration, consulting, and core competencies in areas like Driver Assistance, Interior Electronic Functions, Driveline & Electrification, and Brake Systems (Continental Engineering Services 2023).

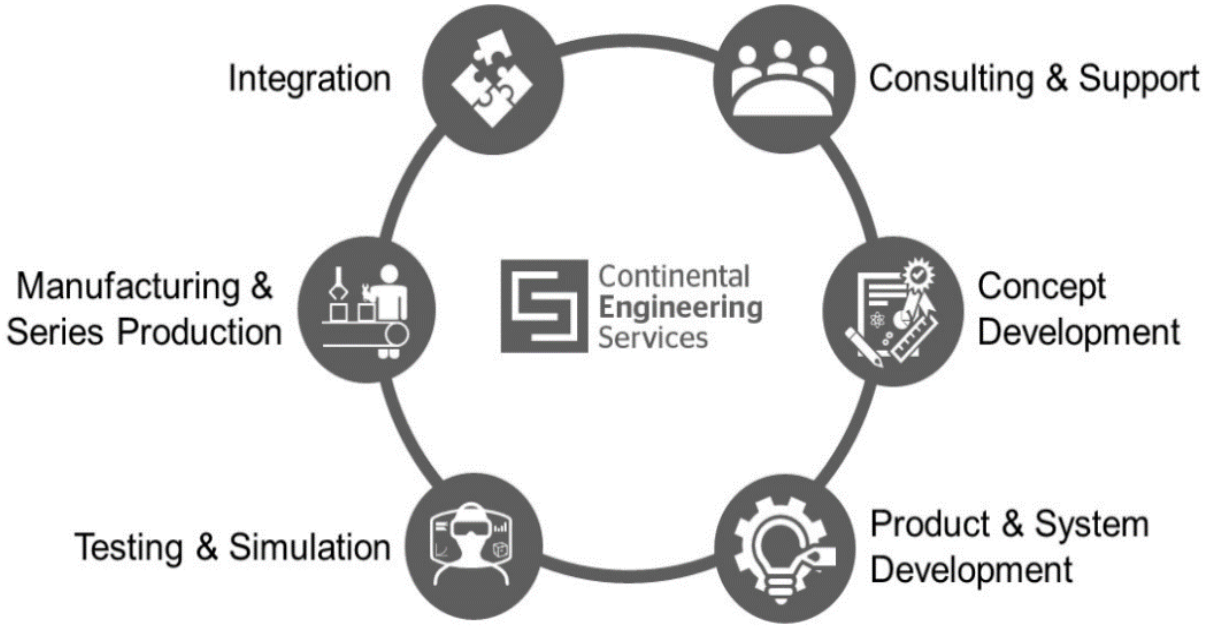


Figure 3: Continental Engineering Services (CES) service portfolio (Continental Engineering Services 2023).

1.2 Problem Description

Traditional quality management practices are prone to human error, delays, and inefficiencies since they rely on manual procedures and paperwork, so a new QMS approach was needed based on the principles and practices of Industry 4.0 (Saihi, Awad, and Ben-Daya 2023). The digitalisation of quality-related data and implementation of business intelligence technologies provided a needed transformative solution.

Business intelligence incorporates data analysis methods and tools to extract insightful information from large datasets. This strategy enables organisations to recognise patterns, identify bottlenecks, and anticipate prospective quality problems (Wang et al. 2022).

The thesis work acknowledges Industry 4.0 technologies and frameworks to fill the gaps in the conventional QMS by reducing operations, enhancing data management, supporting proactive decision-making, and promoting continuous improvement.

1.3 OBJECTIVES

This thesis addresses the incorporation of emerging Industry 4.0 practices into quality management practices in an automotive engineering services company, providing a potential advantage in today's dynamic industrial landscape. It also addresses the identification and monitoring of quality indicators in organisations. The following objectives were set:

- Detailed analysis and creation of reliable communication mechanisms that serve as a tool for continuously measuring and monitoring internal and external quality indicators. This approach promotes informed decision-making and the adoption of measures to improve quality.
- Implementing solutions that enable the automation of quality reports. This is a crucial aspect of the study that seeks to improve the effectiveness of quality management processes by simplifying data collection, analysis, and presentation.
- Ensuring the maintainability of the reports created, recognising their indispensable role in providing reliable knowledge of the company's performance. The effectiveness of well-informed decisions and efforts to improve quality depends to a large extent on the maintainability of their accuracy, reliability, and relevance over time.

1.4 THESIS STRUCTURE

This thesis is divided into five main chapters, each contributing to a thorough understanding of the project's goals and results. The thesis structure is described in the section after that:

The first and current chapter delves into the project's motivation and contextual background. It provides information on the company involved, the problem description, and the proposed objectives. By outlining these insights, a clear understanding of the purpose and importance of the study is given.

The second chapter provides a theoretical introduction to the subjects addressed in the dissertation. It was namely defining a Quality Management System and its impact on a company's success. Additionally, it outlines relevant quality standards and methodologies related to engineering services companies in the automotive sector, highlighting applicable tools, such as Data Analytics and Business Intelligence (BI).

Chapter 3 displays an in-depth exploration of the company's current QMS culture as well as its development practices. It also provides an overview of the methodology applied.

Chapter 4 offers the case's study execution at CES. It clarifies the application of the study's concepts and methodology in a practical setting by outlining various scenarios.

In the fifth and final chapter presents the conclusions of the study. The practical and theoretical contributions this thesis provides are outlined, as well as the assessment of its limitations and further steps to investigate or improve.

CHAPTER 2

LITERATURE REVISION

The successful management of quality is crucial to ensuring the success and sustainability of companies in today's dynamic and competitive business environment, particularly in the automotive sector.

This chapter will begin with a contextualisation of what a Quality Management System (QMS) is, the standards that support its implementation in the industry, the philosophies guiding it, and the software solutions supporting these systems. It also delves into a thorough review of pertinent literature. The transformative effect of digitalisation on QMS is also explored in this chapter, covering essential topics like quality metrics, business intelligence, and data analytics.

2.1 QUALITY MANAGEMENT SYSTEMS IN THE AUTOMOTIVE INDUSTRY

In the automotive sector, Quality Management Systems (QMS) emerge as crucial forces for excellence, promoting the incorporation of standards and best practices. The concept of "quality" is essential since it directly impacts the reliability, safety, and success of new technologies, products, and processes (Almeida da Silva 2022). In this context, quality refers to the extent of accomplishing requirements throughout production, from design and development to manufacturing and delivery (Singh et al. 2022).

The strategic alignment of the QMS with recognised standards enhances credibility and competitive advantage to the companies. Additionally, it promotes the identification and mitigation of risks, improves efficiency, and raises customer satisfaction levels.

Engineering projects' complexity and extensive scope require meticulous documentation and maintenance procedures as essential components of the QMS. These components serve as the cornerstone of compliance with quality standards. The steps and requirements for each stage of development, such as design, prototyping, testing, and manufacturing, are laid out in quality manuals, work instructions, and process documents (Almeida da Silva 2022). Standardised documentation guarantees consistent application of procedures throughout the entire project lifecycle.

This way the QMS and the automotive industry's dedication to quality serve as the foundation to promote innovation, safety, and long-term success. The crucial elements of

this system will be covered in more detail in the following sections, along with best practices, the case study, and an examination of its complexities as they relate to the engineering field.

2.1.1 STANDARDISATION

To improve business performance and respond to customer demands, all activity sectors worldwide have a common standard that provides a structured approach to quality management: ISO 9001 Quality Management Systems. However, specific sectors, such as the automotive industry, face particular demands and difficulties that require specialised standards for quality management. The two standards under consideration in this review— IATF 16949 Automotive Quality Management Systems and ASPICE (Automotive Software Process Improvement Capability Determination)— are those that have been developed to meet the complex requirements of the automotive industry. These emerge from the need to meet customer expectations and comply with safety regulations while addressing complex supply chains and products.

2.1.1.1 IATF 16949 - Automotive Quality Management Systems

The IATF 16949 is an international standard framework for QMS, built upon ISO 9001 and created by the International Automotive Task Force (IATF) in collaboration with major automotive manufacturers (Gruszka and Misztal 2017).

While both IATF 16949 and ISO 9001 share a common foundation, there is some overlap between the standards, they each have unique qualities specific to the automotive industry. The two standards emphasise fundamental ideas like a process-oriented approach to quality management, an emphasis on client satisfaction, and a steadfast dedication to continuous improvement. Risk management, supply chain management, and considerations for the manufacturing process are just a few of the specialised concepts that IATF 16949 introduces and are crucial to the automotive industry.

The importance of thorough documentation cannot be overstated in the context of IATF 16949 — such as FMEA (Failure Mode and Effect Analysis) for products and processes, SPC (Statistical Process Control), MSA (Measurement System Analysis), and the use of APQP (Advanced Product Quality Planning) and PPAP (Production Part Approval Process). The order and description of each document is available in Figure 4.

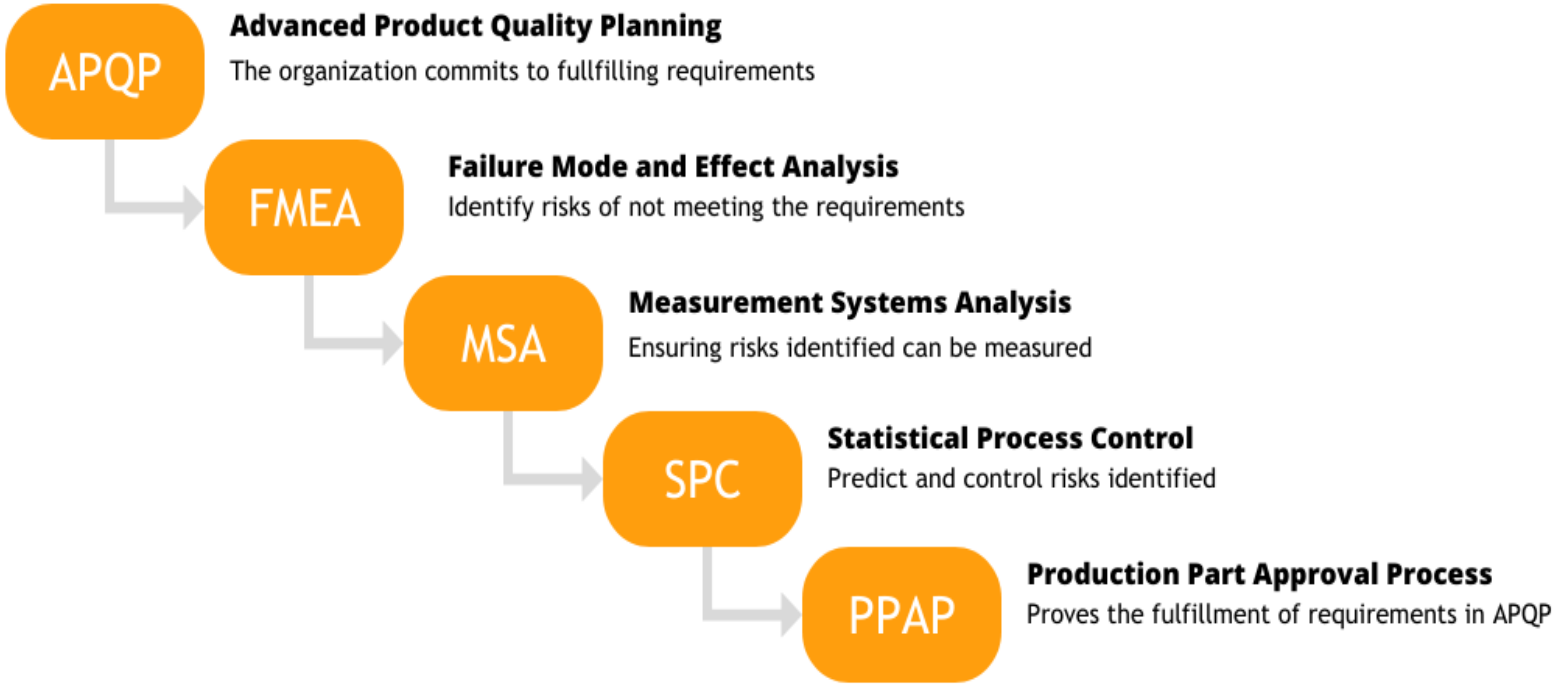


Figure 4: IATF 16949 Five Core Documentation Tools (Plexus International 2023).

In conclusion, IATF 16949 is a crucial standard for quality control in the automotive sector. Its distinctive emphasis on risk management, supply chain management, and product realisation considerations, along with its importance to quality documentation and tools, make it a framework absolutely necessary for automotive manufacturers aiming for the highest levels of quality and customer satisfaction. This standard is more than just a compliance requirement for those looking to succeed in a competitive and demanding industry.

2.1.1.2 ASPICE - Automotive Software Process Improvement Capability dEtermination

The assessment and improvement of software development practices have undergone a significant transformation in the automotive industry in recent years. ASPICE, created to meticulously assess and advance the software development methodologies used within the automotive industry, is a crucial framework in this area (Sameh and EL-Toukhi 2020). It focuses on deeply examining the software development life cycle and outlining the various procedures, jobs, and output work products that produce excellent automotive software solutions.

The landscape of multiple software development life cycle models underlines the wide range of requirements and demands inherent to software projects. These models, which cover the whole range from gathering the first set of requirements to deployment and ongoing maintenance, provide invaluable structured approaches for navigating the challenge of software development. Every model is carefully customised to fit various project scopes, team dynamics, and client expectations while presenting a unique range of advantages and disadvantages that control their suitability (Noureldin et al., 2022).

This standard's structure includes numerous process categories, including but not limited to project management, engineering requirements, software design, testing, and configuration management. In order to ensure that the software produced meets the essential criteria of safety, reliability, and quality, ASPICE places a great deal of emphasis on methodical and disciplined software development paradigms (Noureldin et al. 2022).

Incorporating a robust process reference model, ASPICE methodically defines a range of capability and maturity levels as benchmarks for assessing and improving software development initiatives. The six capability levels spectrum, available in Figure 5, is useful for assessing a company's procedural sophistication, with each level indicating a particular set of necessary process characteristics and procedures. Significantly, the higher levels of capability signify increasingly efficient and refined processes, demonstrating a company's skill in coordinating advanced software development practices.

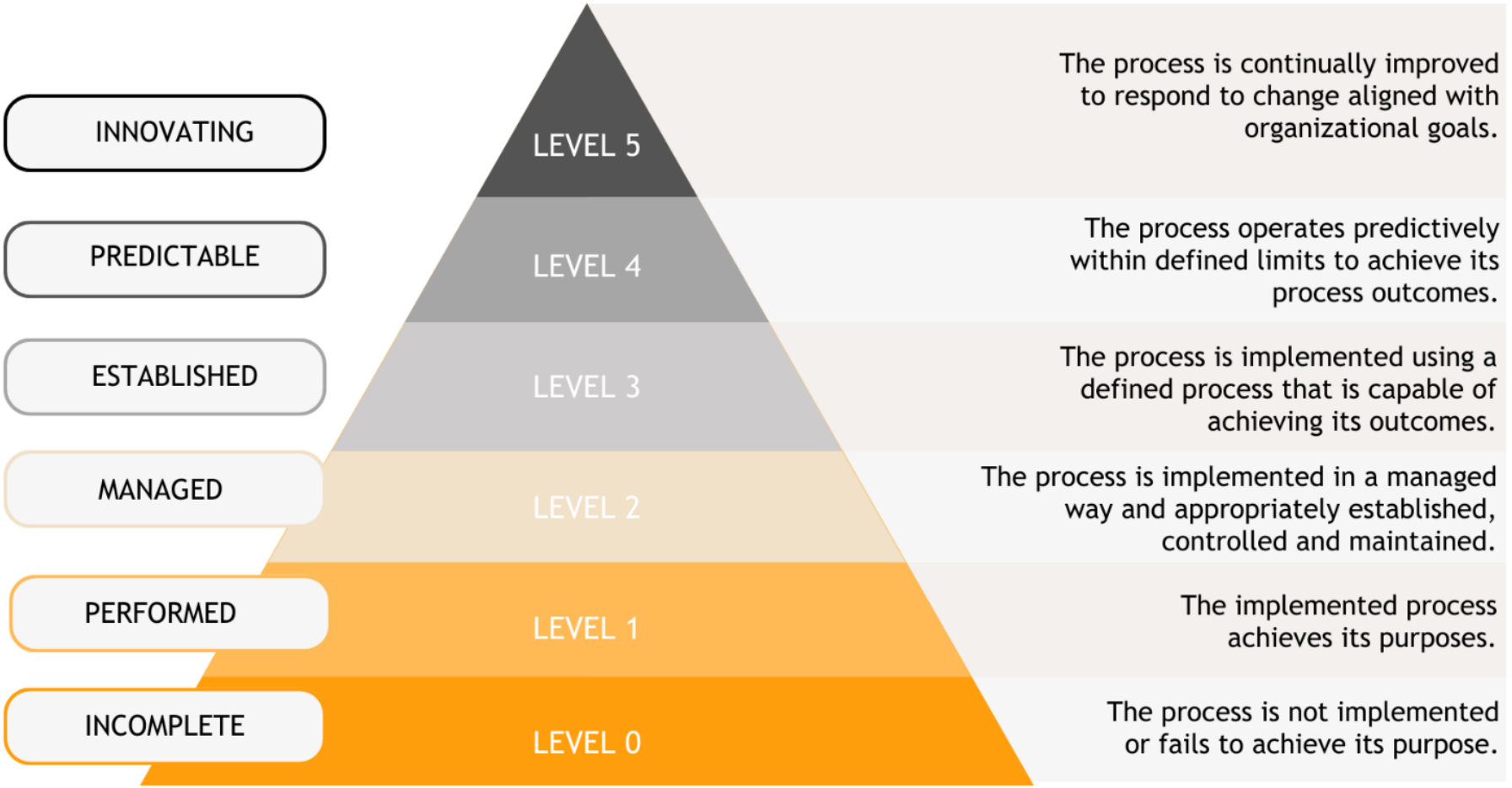


Figure 5: ASPICE capability dimension overview (Noureldin et al. 2022).

In conclusion, ASPICE has played a key role in the advancement of methodologies for developing automotive software. Its comprehensive approach, which incorporates various process categories and elaborates on capability levels, outlines a path toward better software development practices that provide accuracy, efficiency, and the highest level of quality. ASPICE acts as an indicator pointing towards the best possible software development excellence as the automotive industry hurtles forward into a future defined by software driven innovation.

2.1.2 Quality Practices – Frameworks and Tools

As mentioned, the dynamic landscape demands multiple approaches that cater to different business demands and requirements along with industry-specific standards. They continuously look for ways to improve performance, streamline operations, and exceed client expectations. A multitude of strategies and methodologies are available to accomplish these goals, each one tailored to deal with particular business needs and industry standards.

One such strategy is Agile, which recently gained traction in the software development industry. Agile is described as having a quick and adaptable philosophy that promotes continuous iterations throughout the development life cycle of a product (Giacosa, Culasso, and Crocco 2022). It encourages teamwork and initiative, enabling the parallel setup of the development and testing processes. Agile's proactive approach makes it possible to complete the project while ensuring accurate client requirements are followed and reducing its time to market (Behutiye et al. 2022).

Some key concepts associated with an agile framework are mentioned in Table 1. Agile's applicability goes beyond the software industry because its underlying principles have proven useful in many fields, making it a relevant topic for research and analysis.

Table 1: Agile Framework Key Objectives (Gheorghe, Gheorghe, and Iatan 2020).

People-Centred Culture	Cross-function collaboration is essential for a project's success rather than exclusively relying on tools.
Faster Feedback	Agile requires continuous integration, giving stakeholders access to the software's status at any time. This assists in avoiding inaccurate expectations and guarantees that the development team and stakeholders are on the same page.
Efficient Development & Project Management	Agile teams frequently adhere to management methodologies like Scrum, Kanban, and Extreme Programming (XP) to enhance processes. These allow the separation of labour into manageable tasks, which promotes incremental and iterative development.
Collaborative Teams	Close collaboration among cross-functional teams promotes synergy and group problem-solving.

Agile offers businesses a solid framework comprising different methodologies like Scrum, Kanban, and Lean, each offering a particular set of practices and principles to address the various project requirements (Sutherland and Schwaber, 2017). A wide range of tools and software programs intended to facilitate project management, teamwork, and communication are also available to support Agile. These tools, which range from project management programs like Jira to communication tools, enable teams to successfully implement Agile practices and ensure project success (Dikert et al., 2016).

2.1.2.1 Project Tracking Software

The Kanban concept is an Agile project management pivotal methodology for its ability to improve workflow tracking through visual boards segmented into columns that indicate distinct project stages (Weflen, MacKenzie, and Rivero 2022). Each task within a project is represented by a ticket, which gives team members an understanding of the current project status. A visual representation of this tool is available in Figure 6. The Kanban board acts as a mechanism for restricting the tasks in progress, thereby preventing the overload of individuals and encouraging a continuous workflow in line with the team's capacity (Alaidaros and Omar 2018).

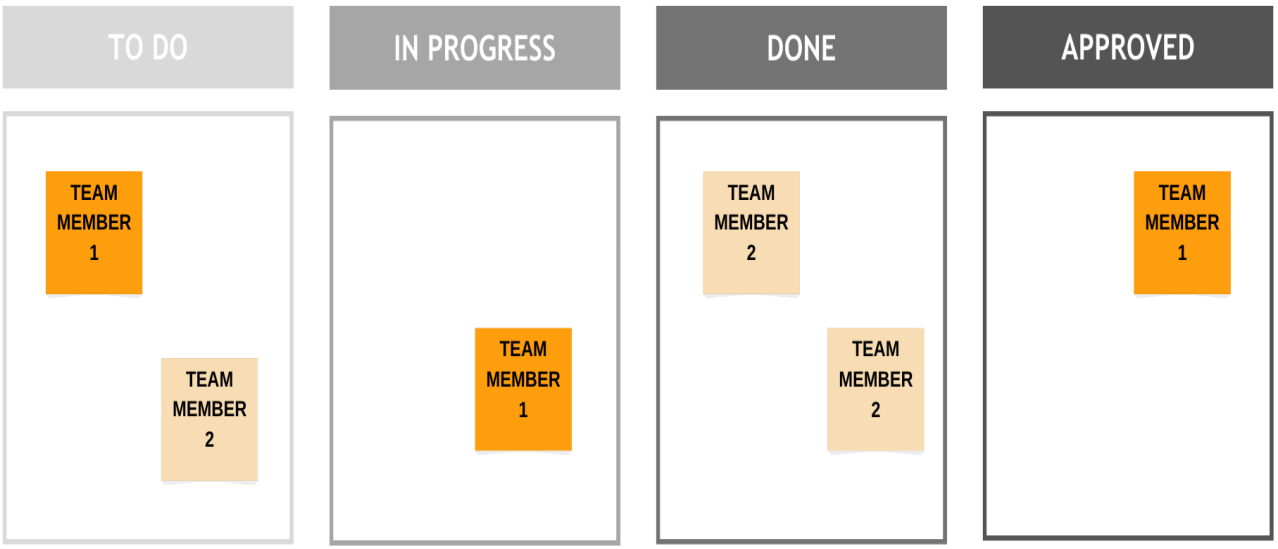


Figure 6: Kanban Board Configuration (Mircea 2019).

It is important to note that using the project tracking software in conjunction with the Kanban approach provides a robust and complete platform for efficient project management, facilitating the maintenance of high-quality standards.

"Project tracking software" is a term used to describe a digital tool created to help teams plan, organise, and manage projects as efficiently as possible (Damij and Damij 2021).

A key component of project tracking software, task management is the most important of these features. Users can create tasks, assign them to team members, and set task priorities using this functionality. Doing this promotes team members' sense of accountability and improves the transparency of project execution. Furthermore, task management encourages the division of complicated tasks into smaller, easier-to-manage subtasks.

Progress tracking is also a crucial feature of project tracking software that enables users to closely monitor how tasks and projects are progressing. Tools like progress boards, Gantt charts, and timelines are frequently used in this functionality. These tools support project managers and team members in locating bottlenecks, setting task priorities, and guaranteeing the timely completion of projects.

In conclusion, project tracking software and the Kanban methodology effectively support modern project management. Project tracking software enables teams to effectively manage tasks, monitor progress, and ultimately deliver high-quality results in a timely manner, whereas Kanban streamlines workflow and ensures the optimisation of team capacity.

2.1.2.2 Web Collaboration Software

Web collaboration software has also emerged as a powerful tool for seamless teamwork across geographic boundaries. The collaborative efforts of individuals within a project or organisation can be streamlined using a variety of applications and online platforms (Wu and Sahraoui, 2004).

As teams are now dispersed across the globe in modern work environments. The introduction of web collaboration software has old barriers to communication and collaboration being tested. These digital platforms enable teams to work together quickly regardless of location, laying the groundwork for effective project management and quality improvement.

The availability and accessibility of accurate documentation are crucial for quality management. Web collaboration software provides a central location where project, process, and quality standard documentation can be kept and accessed by authorised staff. This centralisation may lead to less chance of mistakes and outdated information since everyone has immediate access to the most recent documents.

The cornerstone of quality management is cooperation. Web collaboration tools also give team members a virtual forum to strategise, exchange concepts, and work together to solve quality-related problems. Real-time chat, video conferencing, and group document editing tools encourage lively conversations among team members, which fosters creativity and productivity.

A valuable resource in quality management is knowledge. Software for web collaboration makes it easier for team members to share knowledge and experiences through discussion forums, knowledge bases, and collaborative platforms, which results in a workforce that is more knowledgeable and competent.

A crucial element of quality management is efficiency. Project planning and task tracking are just two of the many processes that web collaboration software streamlines. The efficiency of quality-related processes is improved by automation features, workflow management, and integration with other software tools, which lowers manual errors and saves valuable time.

The adoption of web collaboration tools helps to foster an organisational culture that is focused on quality. Employees are more likely to be engaged and committed to quality improvement initiatives when they have the resources necessary to collaborate successfully and have access to crucial quality-related information.

In conclusion, web collaboration tools have become an essential enabler of quality management procedures in modern businesses. The efficiency and effectiveness of quality initiatives are significantly increased by their capacity to centralise documentation, promote collaboration, foster knowledge sharing, and streamline processes. Organisations can create a culture deeply rooted in quality by utilising the power of these tools, setting themselves up for long-term success in a market that is becoming more and more competitive.

2.2 Digitalisation of Quality

With the growing importance of data and technological advances, digitalisation has revolutionised companies' approach to quality management. The usage of software and tools enables the digitalisation of a company's quality data, this process helps to streamline and improve the procedures and activities related to quality management. An ongoing effort has been made in companies to incorporate Big Data and Business Intelligence on quality topics, as real-time data visualisations play a key role in decision-making.

The automation of repetitive and manual tasks, such as data collection, documentation, and reporting, is not only a time-saving improvement but also an approach to minimisation of human error, leading to overall increased quality performance. This enhances the identification of bottlenecks, elimination of inefficiencies, and implementation of best practices. It is crucial for businesses to stay current on the most recent advancements in digitalisation as technology is constantly changing.

2.2.1 Quality Metrics

Quality metrics play a pivotal role in modern organisations, as they are quantifiable measurements of a product, process, or service's quality. They provide objective information and insights into a range of quality-related topics, assisting companies in their performance evaluation and detecting areas for development (Parmenter 2015). These Key Performance Indicators (KPIs) are crucial instruments in the QMS to monitor, regulate, and improve corporate operations (Melnyk, Stewart, and Swink 2004).

By monitoring the quality metrics progress, companies can identify areas of improvement and investigate their root cause and corrective actions, allowing the follow-up of each step to make data-driven decisions to enhance quality. The alignment of KPIs with changing organisational objectives and customer expectations ultimately promotes a quality culture throughout the organisation.

It's essential to understand that choosing the right quality measurements relies on the specific context, sector, and company goals (Badawy et al. 2016). Metrics must be quantifiable, pertinent, and consistent with the broad quality objectives. The focus and purpose help classify a quality metric into different categories:

Product Quality Metrics: These KPIs evaluate the extent to which specific quality requirements are met, such as reliability, durability, functionality, and conformance to specifications.

Process Performance Metrics: These focus on the effectiveness and efficiency of production or service delivery processes. Their monitoring helps identify bottlenecks, measure cycle times, reduce waste and improve overall performance.

Customer Satisfaction Metrics: These metrics estimate customer satisfaction and loyalty towards a product or service. They provide valuable feedback on customer expectations, preferences, and perceptions.

Cost-Related Metrics: These assess the financial impact of quality-related activities, helping to evaluate the cost-effectiveness of quality management efforts and identify opportunities for cost reduction.

Compliance Metrics: These KPIs include training and certification levels, adherence to quality procedures, and involvement in continuous improvement initiatives.

In conclusion, quality metrics are essential in contemporary organisations as they provide a structured method of evaluating and improving quality. They support an organisational-wide quality culture and improve the overall effectiveness of quality management systems (QMS). The specific organisational context, sector, and goals all influence the choice of suitable quality metrics. Organisations can gain a thorough understanding of their quality landscape by classifying quality metrics into distinct types, paving the way for ongoing development and sustained excellence.

2.2.2 Big Data Analytics

Big Data Analytics (BDA) is the process of studying and acquiring important insights from large and unstructured datasets from multiple sources. Innovative analytic techniques and tools created specifically for Big Data enable users to identify patterns, trends, correlations, and other meaningful information (Watson 2014).

This process encompasses several stages (Klašnja-Milićević, Ivanović, and Budimac 2017), including:

1. **Data Collection:** Each company has a different approach to data collection. Thanks to modern technology, organisations can gather data from an array of structured and unstructured sources.

2. **Data Storage:** The collected data is stored in a centralised or distributed system, such as data warehouses, data lakes, or cloud-based platforms

3. **Data Cleaning and Process:** Once data has been gathered and stored, it must be organised to produce accurate results from analytical queries.

4. **Data Exploration and Analysis:** Once data is ready, its initial understanding is needed for interpretation, followed by applying statistical analysis, machine learning algorithms, data mining techniques, and other advanced analytical methods.

5. **Visualisation:** Through dashboards, reports, and visualisations, the analysis outcomes are interpreted and effectively shared with stakeholders. Decision-making is aided by visualisation techniques to present complex information in an easily understandable and accessible manner.

The insights and actions taken from data analytics are as valuable as the difficulty of its exploration (Smaya 2022). The following graph (Figure 7) showcases the relationship between these two variables, as well as the different techniques of analytics used:

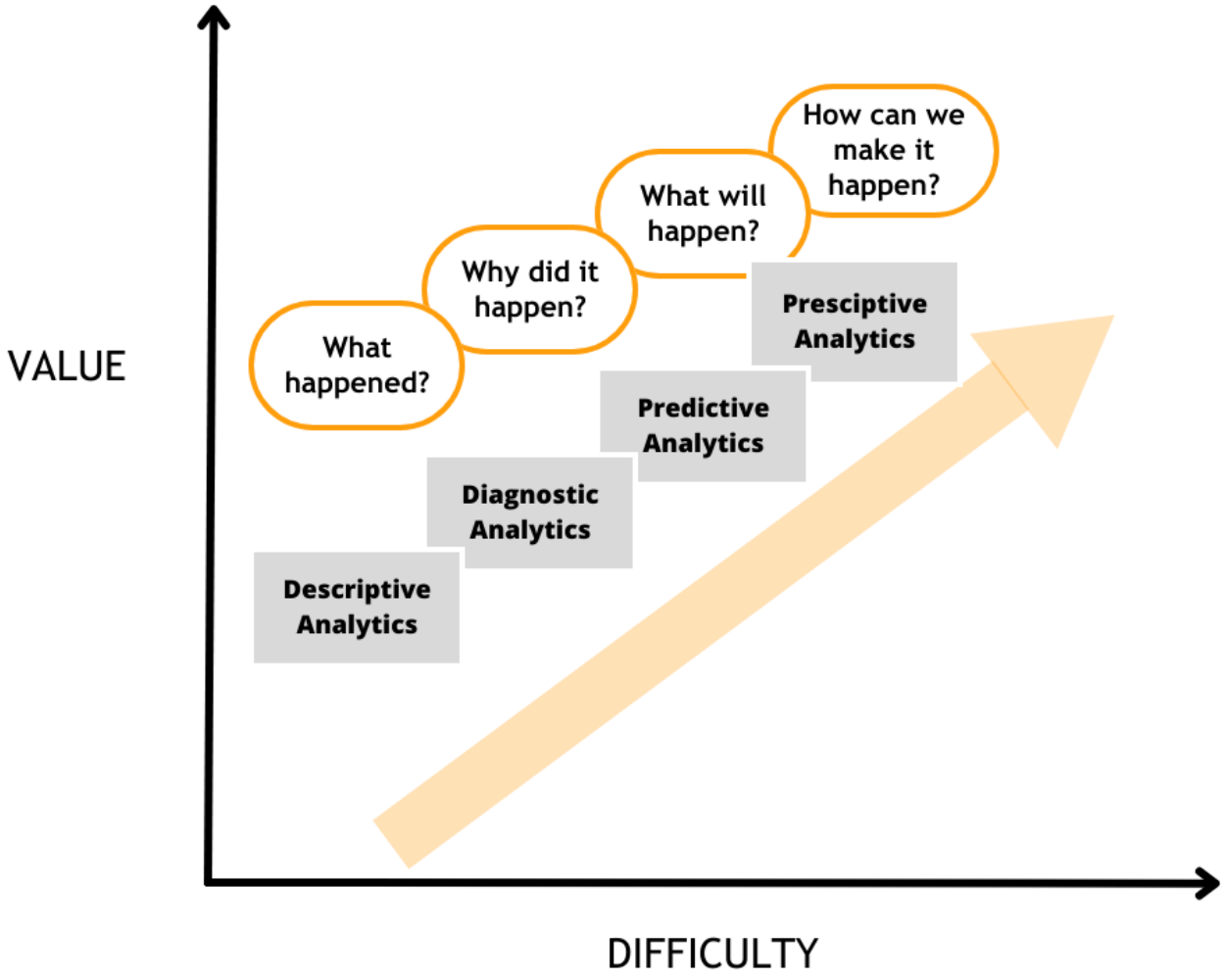


Figure 7: Graphical representation of the relationship between data analytics and insights (Sansom 2022).

2.2.3 BUSINESS INTELLIGENCE

Over time, the distinction between analytics and Business Intelligence (BI) platforms has become blurred, and the majority of enterprise options now provide some of each (Brooks 2023).

In a world where data rules, it is more important than ever for businesses to comprehend how to take advantage of the abundance of digital insights at their disposal (Datapine 2019). Additionally, the increase in data that was made available required the need for higher processing and analysis skills.

Business intelligence (BI) is an effective set of tools and technologies that allows companies to transform vast amounts of unstructured data from several sources into valuable insights (Datapine 2019). In the context of quality management, BI is essential in assisting organisations to track, evaluate, and enhance their overall quality metrics.

The development of dashboards, which offer a visual representation of pertinent KPIs, is one of the primary applications of BI in quality management. It enables stakeholders to grasp quality performance quickly and intuitively, with real-time monitoring and analysis across all company stages.

The creation of a BI system requires an understanding of its architecture, consisting of 5 layers, presented in Figure 8.

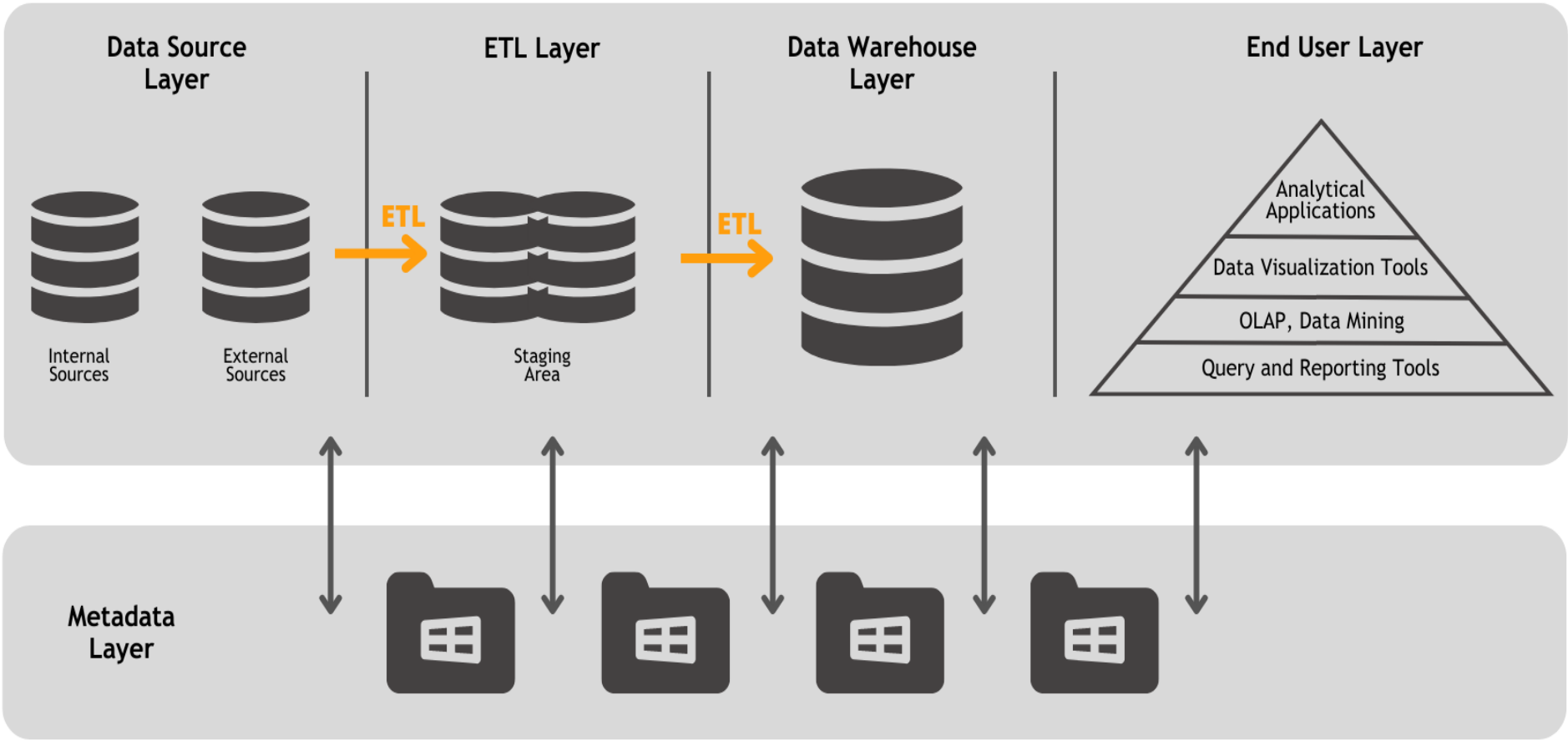


Figure 8: BI Architecture (Ong, Siew, and Wong 2011).

The BI System starts with the Data Source Layer, obtained within the collection of different databases. The information is retrieved through an Extraction, Transformation, and Loading (ETL) process, where stages of combination, integration, and aggregation are performed to obtain a consistent format for analysis. The Data Warehouse integrates the data that comes from the ETL process.

Data regarding what is available in each layer, how it is related, and how it is organised is stored in the Metadata layer (Sen and Sinha 2005). The applications and tools used by the end user, such as dashboards, reports, or analytical applications, are incorporated in the final layer, typically referred to as the dashboard layer.

There are many different types of BI users, including IT developers, front-line staff, analysts, managers, executives, suppliers and customers, and the application should have different requirements for each of these users. Managers and front-line employees are more likely to use reports and dashboards than IT developers and analysts, who may need to write SQL queries and create new visualisations (Watson 2009).

BI systems play a fundamental role in efficient quality metric identification and follow-up, by providing automated tools and reports that allow companies to measure, monitor and promptly identify trends, patterns, or areas of improvement.

The streamlining of data collection and analysis processes eliminates the need for manual and time-consuming tasks, reducing the likelihood of human errors and improving efficiency. Ensuring the reliability and accuracy of the developed tools and reports is a must and requires proper maintenance. This process includes regular updates, data validation, and performance monitoring.

While leveraging BI for dashboard creation in quality management offers numerous benefits, organisations should consider sensitive information is often present in data. Therefore, data integrity, confidentiality, and privacy must all be protected by implementing suitable security measures. These measures should encompass robust access controls, encryption techniques, and regular security audits to safeguard sensitive information from unauthorised access or breaches.

2.2.3.1 ETL – Extract, Transform, and Load.

As previously mentioned, businesses have multiple databases from different sources containing untreated information. All the data used in the system will come from these databases, meaning they won't be in the same format and ready for the intended goal. ETL, which stands for Extract, Transform, and Load, is the process used to address this problem. It entails extracting the data, transforming it in a staging area, and then loading it into a data warehouse or data mart (Watson 2009).

The Extract stage of the process begins with the analysis, identification, and collection of relevant information from various sources (Muhammad et al. 2014). This can be done manually by developing code (typically using SQL queries), however, there are better options on the market, such as data integration software.

Most frequently, the data gathered is incomplete, duplicated, or connected to other systems (Ong, Siew, and Wong 2011). This problem will be solved during the Transform phase. The data is then transformed after it has been extracted and sent to a temporary storage location (Awasthi 2012).

Besides correcting all possible errors and problems, the data must be ready for reports and analysis. After the transformation, the data is loaded into a different database during a load window, which is getting smaller as businesses transition to operational BI because real-time BI requires a low refresh rate (Watson 2009).

2.2.3.2 Data Warehouse

A data warehouse refers to the database that is used to load data. The definition of a Data Warehouse, one of the most significant elements in a BI architecture, is "a subject-oriented, integrated, time-variant, and non-volatile collection of data in support of management decision-making process" (Inmon 2005). For better analysis and comparisons, Data Warehouses typically keep data for longer than standard databases (5 to 10 years), and they are updated frequently (weekly or daily), so they will always have the most recent information (Al-Noukari and Al-Hussan 2008).

Application support for OLAP (Online Analytical Processing), are the best systems suited to support decision-making queries and make it simpler to respond to business questions. It is an easy-to-use tool that enables faster analytics, such as data aggregation, drill-down, or slicing and dicing (Sen and Sinha 2005). This aids the Business Intelligence process, which frequently calls for these functionalities in addition to filtering and pivoting (Chaudhuri, Dayal, and Narasayya 2011).

CHAPTER 3

CASE STUDY

3.1 QUALITY MANAGEMENT SYSTEM AT CES

A comprehensive analysis of the current Quality Management System (QMS) was necessary to accomplish the goa objectives outlined in this master's thesis. This evaluation sought to close the gap between theoretical concepts and actual implementation in an organisation that provides automotive engineering services. The valuable insights obtained will serve as a solid foundation to implement efficient improvement strategies in the QMS of the automotive engineering services company.

This study's purpose was to understand better the methodologies, tools, and best practices used by the company's quality team. The objective was to gather insightful data that would guide the initiatives for improvement. The company's Quality Management System Manual, which holds relevant mandatory quality-related directives, was examined to gain these insights. This manual contains a reasonable and appropriate framework that actively involves every employee in the planning and execution of projects.

The QMS framework consists of several vital components, each essential to the organisation's success. The management of resources, creation of products, measurement and analysis, and continuous improvement are all included in this group. It is imperative to stress the importance of these factors in developing a zero-failure culture, improving client satisfaction, maintaining competitiveness, and methodically mitigating risks.

To ensure the performance of the QMS, the documentation is meticulously organised under the ten process areas outlined in the Process Map (Figure 9). The seamless alignment of rules and all pertinent organisational aspects made possible by this structured approach makes the QMS more transparent horizontally and vertically.

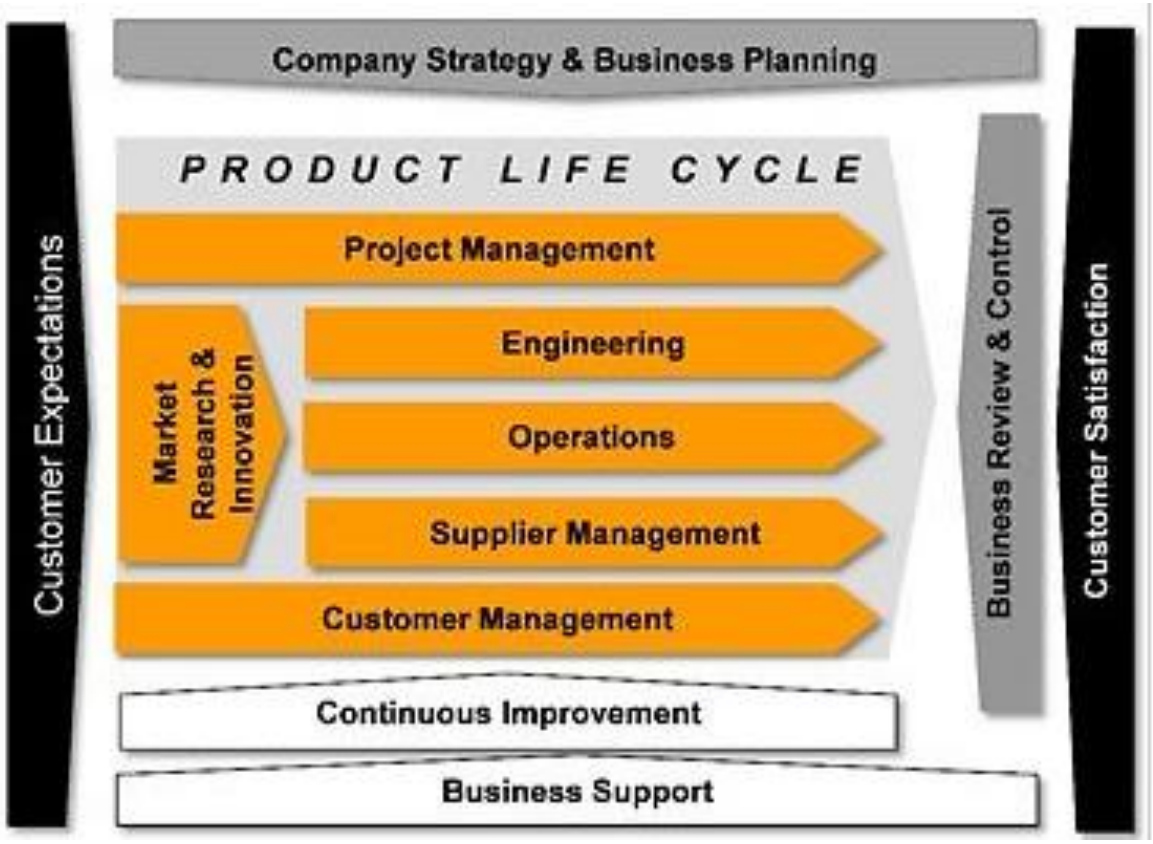


Figure 9: Continental Process Map showing the ten binding process areas.

Furthermore, it is essential to note that the QMS strictly complies with the IATF 16949 standard clauses by adhering to the recommended guidelines, with more specific information being addressed at lower levels and within customer projects. The consistency of task execution is ensured by the structured documentation and adherence to the "House of Rules" framework and ten process areas of the Process Map, which also supports the efficient operation of the QMS. The highest levels of performance and quality are upheld within the organisation in large part thanks to this all-encompassing strategy.

3.1.1 Current Practices and Tools

The Quality Management System (QMS) at CES is examined in depth in this case study, with an emphasis on how crucial it is to ensuring the delivery of high-quality services. As an engineering services provider, CES upholds Automotive SPICE capability level 2 and follows the IATF 16949 standard, demonstrating its dedication to process compliance and maturity. CES has integrated several crucial processes within its QMS in order to manage quality and promote continuous improvement.

CES has established the following key processes within its QMS to manage quality and encourage continuous improvements efficiently:

Document Control: An essential activity that ensures proper creation, review, approval, and distribution of documents.

Audits: Both internal and external audits are conducted to ensure adherence to adopted standards and identify process gaps.

Supplier Management: A crucial process involving the assessment, quality assurance and reliability of supplier's products and services is employed.

Customer Feedback: Designed to gather customer input, complaints, and suggestions to improve overall services. These may incorporate customer surveys, feedback forms, warranty claims, and customer support interactions.

Recognising the need to enhance collaboration, increase efficiency, and speed the delivery of high-quality projects in today's quickly changing digital landscape, the company has adopted agile methodologies and integrated strong tools into its workflow to meet the demands of a rapidly evolving digital landscape.

One of the key tools implemented is Jira. This project tracking software uses an agile methodology concept to assign tasks, establish deadlines, monitor the status, and ensure the timely completion of a project using the Kanban approach (Atlassian. Jira Software). A Jira platform screenshot usage example is available in Figure 10.

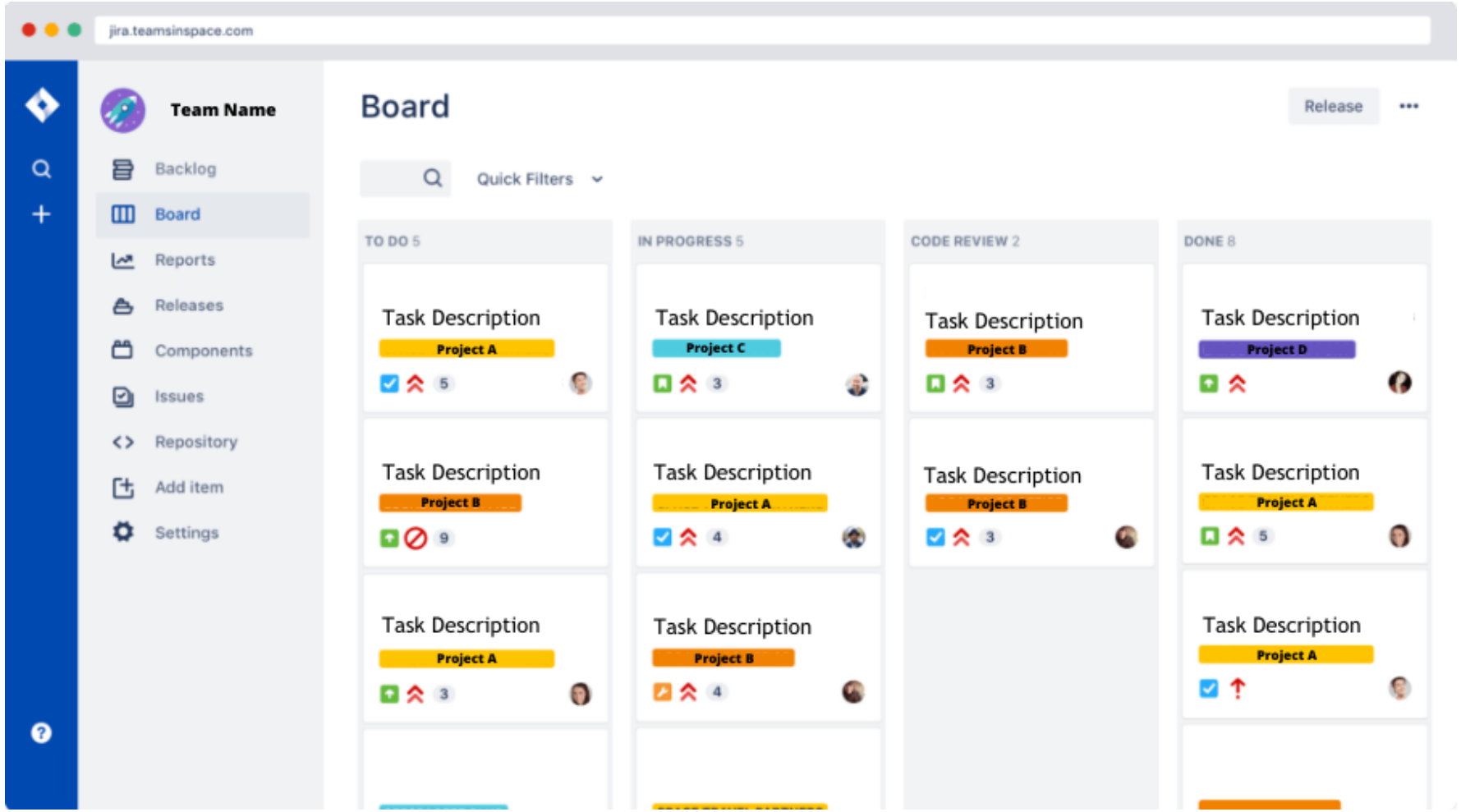


Figure 10: JIRA Software platform screenshot

To further develop collaboration and knowledge sharing, CES implemented the usage of Confluence into its workflow, a centralised platform for creating and sharing documentation (Atlassian. Confluence Software). This software fosters cross-functional communication, promoting teamwork and alignment toward QMS goals.

The commitment of CES to providing high-quality services is upheld by its diligent adherence to industry standards and integration of crucial QMS processes. Additionally, the company has successfully adapted to the dynamic challenges presented by the digital era by implementing agile methodologies and using collaborative tools like Jira and Confluence. To achieve excellence in quality management and collaboration, this case study uses CES as an example of a business that combines industry knowledge with cutting-edge methodologies and tools.

3.1.2 Quality Reporting

Quality reporting plays a pivotal role in evaluating a company's performance and identifying areas that need improvements. CES has carefully chosen and created a set of Key Performance Indicators (KPIs) spanning diverse domains, including customer satisfaction, project management, engineering performance, supplier management, customer management, and more, given the complexity and breadth of the data that requires monitoring.

CES used Microsoft Power BI to pursue a comprehensive strategy for high-quality reporting. This group of software services, programs, and connectors seamlessly combines various data sources, such as databases, websites, and structured files like spreadsheets, CSV, XML, and JSON. The extensive abilities of Power BI include data preparation, data discovery, and the development of interactive dashboards (Microsoft Corporation, 2023).

Power BI broadens the scope of its functionality by also offering the usage of Data Analysis Expressions (DAX) programming, this feature creates new measures within the databases seamlessly and effortlessly. Programming in DAX is comparable to Excel programming, and most functions are cross-platform, however, Power BI also provides some that are more focused on working with relational data.

The dashboard flow's goal is to give users a complete picture of the quality processes, which it does through a number of stages, each with a different emphasis. The information users need can be accessed quickly thanks to the thoughtful design of these stages. Each QMS category report page has been carefully developed to outline the report's specific objectives and associated Key Performance Indicators (KPIs), providing a clear and succinct overview of pertinent quality metrics.

The KPI History reports, which give stakeholders a thorough analysis of particular KPI trends and pertinent information, are one of the enhanced dashboard's key features. This feature gives users the ability to delve deeply into historical data, facilitating a thorough understanding of quality trends over time.

Tooltips are strategically used throughout the dashboard to further improve the user experience. When users hover over particular data points or design elements, tooltips function as educational guides, providing context and additional information. Users who use this feature can better understand complex data and make more informed choices.

Users can drill down into particular data points, use filters, and gain a deeper understanding of the quality processes thanks to the dashboard's interactive nature. This level of interaction allows stakeholders to reach complex conclusions and pinpoint potential areas for improvement, which significantly enhances the quality reporting process.

It's crucial to remember that the reports shown in the created dashboard are periodically reviewed and updated. The information is updated to reflect changing industry standards and the company's strategic goals.The existing dashboard at CES has the flow structure represented in Figure 11.

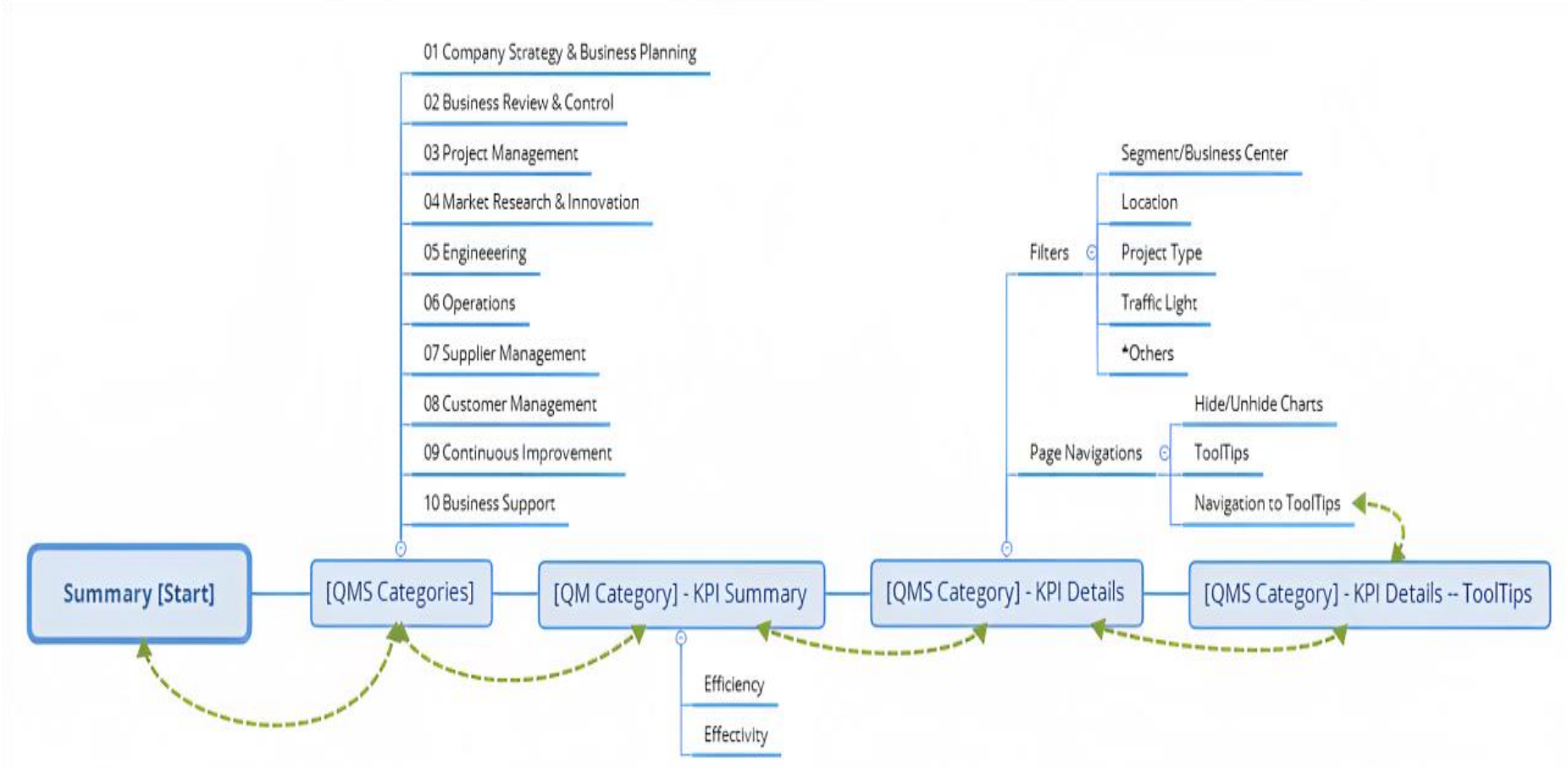


Figure 11: CES Power BI dashboard flow structure.

3.1.2.1 Reporting Key Performance Indicators

KPIs are indicative of a company's effectiveness both in terms of how they are defined and how they are communicated, particularly to the teams and stakeholders involved. The selection of the reporting method is crucial for facilitating quicker decision-making and more accessible data interpretation for those involved in the processes (Yin, Lijun, and Wei 2009). Action plans can be created using real-time data.

The primary performance measures are reported monthly, weekly, or even daily. A previously established table is the most suitable method for reporting these metrics (Parmenter 2015). However, using these table reports when dealing with individual measures may fail to identify trends, detect unusual events, or provide a prediction statement.

Chart presentations can be used as an alternative to table reports. Comparing performance from month to month or year to year is similar to summarising the data in a table, but it has the advantage of generating theories about the past (Lam and Bengo 2003). However, this type of chart is not intuitive because it is challenging to read, prone to erroneous interpretations, and capable of drawing contradictory conclusions (Breyfogle 2008).

3.1.2.2 Dashboards

For corporate managers, the large amount of information that influences decision-making has become a significant problem. As a result, BI technology that enables data organisation has emerged as a promising solution.

The difficulty lies in properly combining all the data to develop an information-based strategy (Pauwels 2009).

Dashboards can be considered another reporting technique businesses use to share and display KPIs. They serve as a tool for employees to address needs. A dashboard is a visual and interactive performance management tool that presents on a single screen the most crucial data required to accomplish one or more personal or organisational goals, enabling the user to identify, explore, and communicate problem areas that need to be addressed (Yigitbasioglu and Velcu 2012).

One of the most significant features of dashboards is the integration of multiple sources in three different ways (Pauwels 2009):

Data: Incorporates data from various sources and across time periods at different levels of aggregation.

Processes: Enables management to connect inputs to financial controls and even management performance indicators.

Viewpoints: allows workers from different locations or departments to share the same equally weighted input, ensuring that everyone in the company views the market situation in accordance with the same principles.

To meet the needs outlined above, standardisation of metrics across departments and business units is facilitated by enforcing standardised measurement procedures. Furthermore, selecting the displayed metrics enables communication with stakeholders about performance and the organisation's goals (Pauwels 2009).

The most crucial decision support system today is the dashboard. To maximise their potential, designers should keep certain guidelines in mind when creating them in terms of the content, features, and visualisations.

When using colours, positions, shapes, texts, and symbols to enhance visualisation, it's important to exercise caution because overuse can distract the user and impair decision-making. It's essential to strike a balance between the utility of the information and visual complexity.

Finally, dashboards must be intuitive to use, clean, simple, and concise. By combining all these traits, users will be able to focus on the most important and urgent data, supporting better decisions. This will make dashboards a suitable solution to improve action-taking and, ultimately, business performance.

There are several methodologies to build a dashboard to ensure effective communication and visualisation of the data. The main stages of the process are represented in Figure 12.

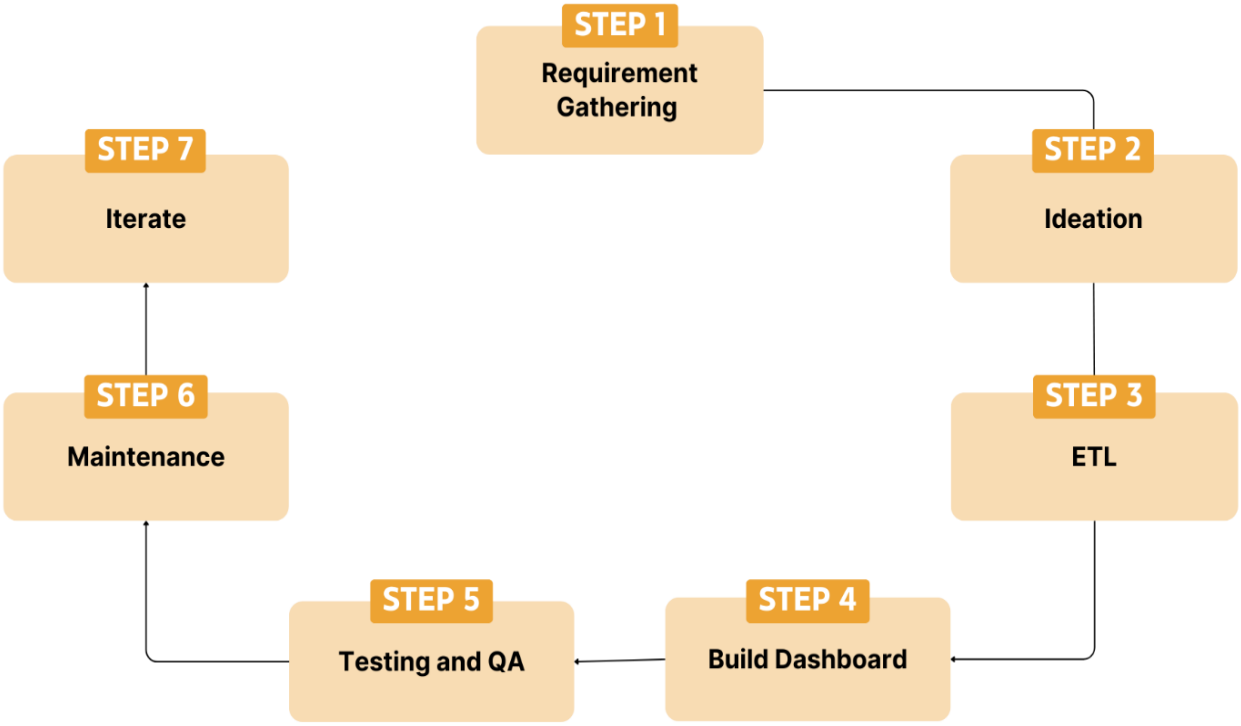


Figure 12: Process steps to build a dashboard (Kintz, Kochanowski, and Koetter 2017).

Gathering requirements is the first step in the process, during which several interactions with stakeholders take place to learn about their needs and expectations. An assessment of key metrics, data sources, and functionality needed for the dashboard is defined through discussions and interviews. These specifications act as a roadmap for the creation process.

The ideation phase is a brainstorming session to develop original designs and layouts for the dashboard, similar to the one available in Figure 13. It includes researching ideas and sketching potential designs while considering the target audience and the dashboard's purpose. This phase is essential for establishing the visual representation of the dashboard.

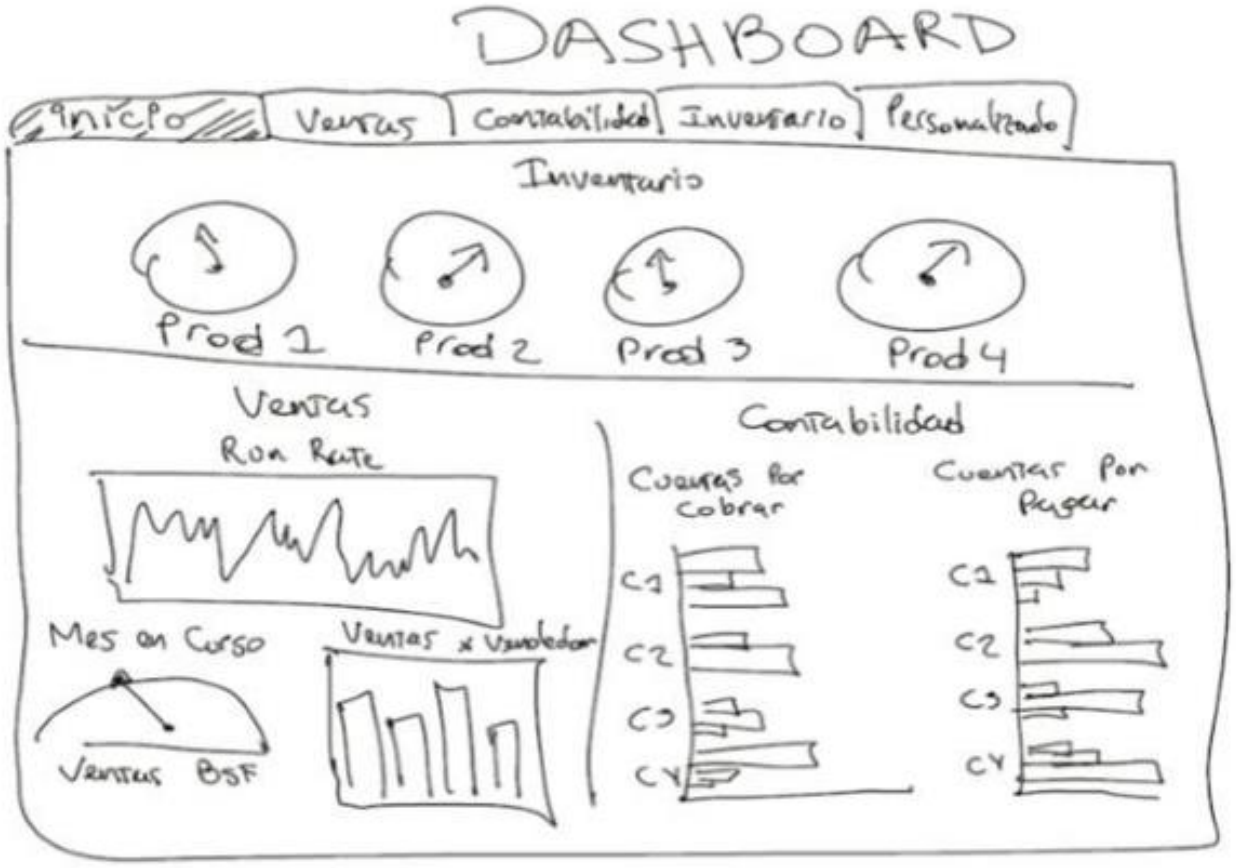


Figure 13: Pen and Paper example of ideation takeaway.

The ETL process takes place once the requirements and design concepts have been defined.

With the transformed and loaded data, the building of the dashboard itself can start. This step includes creating visualisations, arranging components, and applying design principles using a chosen dashboarding tool or piece of software. This is followed by implementing interactivity, filters, and drill-down functionalities utilising the tool's features, which improves user experience. The KPIs and metrics are calculated, and visual representations are used to offer insightful data.

After creating the dashboard, testing and quality assurance (QA) are performed. A thorough testing process guarantees precision, usability, and functionality. The dashboard is deployed and starts to be used by stakeholders after being successfully tested. The process doesn't stop there, though. In order to maintain the dashboard's effectiveness, regular maintenance is required. Important tasks include frequently updating data sources, refreshing data, and handling bugs or performance problems.

As the creation of a dashboard is an iterative process, changing needs and expectations may arise with continuous feedback gathered from users, stakeholders, and data consumers. The design and functionality of the report are enhanced based on the feedback input.

3.1.3 Data Analysis

Data analysis aims to produce insightful conclusions from the data collected. In this study, we will emphasise using the CRISP-DM (Cross-Industry Standard Process for Data Mining) methodology, one of many frameworks and approaches for data analysis.

This framework offers a systematic approach that leads decision-makers through every step of the data analysis procedure, from comprehending the issue to applying the findings. It consists of six major phases, displayed in Figure 14 cycle.

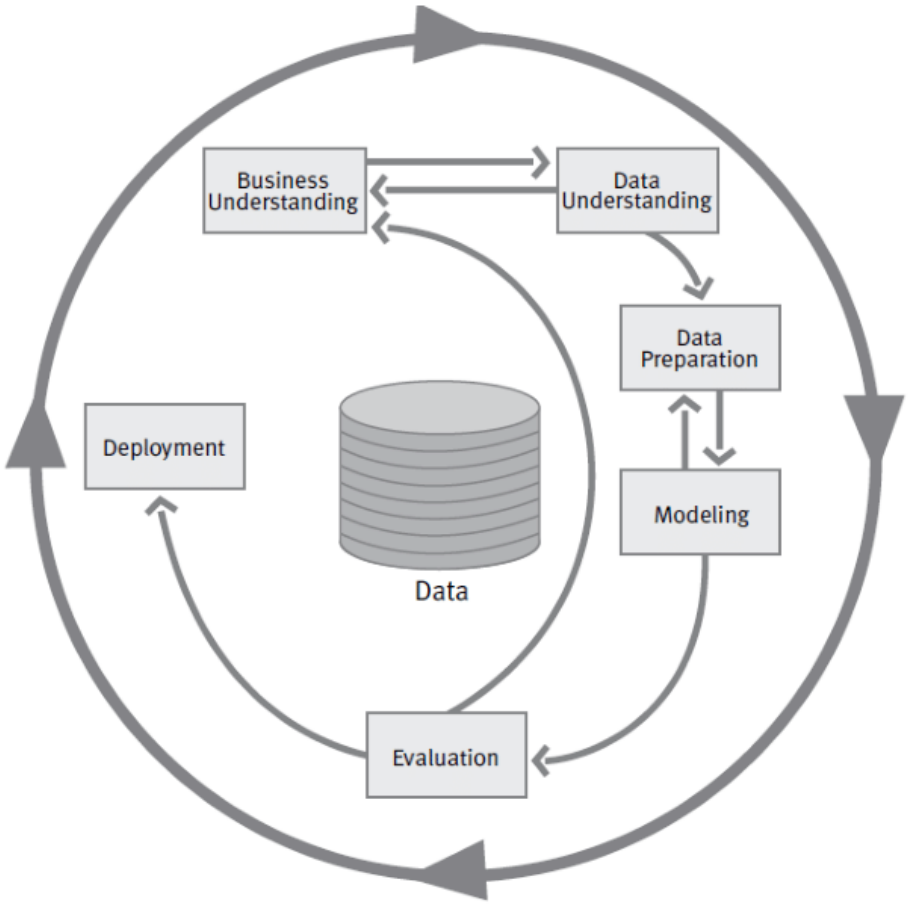


Figure 14: CRISP-DM Methodology Framework (Colpani. 2019.)

The objectives and questions to answer are formulated in the Business Understanding phase, and the scope is also identified. This step will lay a strong foundation for the following stages of data analysis.

The available data is explored and analysed in the Data Understanding phase to learn more about its qualities and relevance to the goals. Data profiling techniques like summary statistics, visualisation, and exploratory data analysis will be used to understand the data better.

The Data Preparation involves several steps, such as data cleaning, handling missing values and outliers, and transformation into a suitable format for analysis. This stage might require the application of integration techniques if multiple sources are used.

In the Modelling phase, the prepared data is subjected to selecting and applying suitable analytical methods. Building models that can answer the problem requires statistical and machine-learning algorithms.

The models developed in the previous stage will be examined to determine how well they perform and how well they address the problem. The data analysis outcomes will then be deployed to the problem context. Depending on the objectives, this might entail developing visualisations, producing reports, or integrating the models into operational systems.

CHAPTER 4

APPROACHES FOR IMPROVEMENT

This chapter focuses on the initiatives to implement advanced analytics and Business Intelligence (BI) tools. The proposed initiatives exemplify how the company can improve customer satisfaction, rely on data-driven decision-making, and optimise project execution through the effective usage of Power BI reporting.

A comprehensive set of tasks was undertaken to fulfil the proposed thesis objectives and extend the knowledge on the topic of study. These tasks were either directly available on the company's Jira platform or determined through carefully analysing the current QMS practices. The following sections include the presentation and description of relevant KPIs on the tasks, as well as the application of the methods described above.

4.1 REPORTING KEY PERFORMANCE INDICATORS AND MONITORING

The first objective of this study is to streamline the procedure for identifying and monitoring internal and external quality metrics. The development of tools and reports to efficiently track and address these metrics is key to achieving this goal.

Key Performance Indicators (KPIs) that are task-specific are presented and described in detail in this section. These KPIs are crucial in determining each task's success and development as part of the advanced analytics and BI implementation initiatives.

Using reliable and well-defined methodologies is crucial to the success of the initiatives. This section presents more details about the methodologies used to implement advanced analytics and BI.

This section aims to clearly understand how the methodologies contribute to achieving the proposed objectives and enhancing the organisation's data-driven capabilities by methodically outlining the approach taken.

4.1.1 Creation of a QMS Category Report

The Customer Satisfaction metrics at CES are crucial Key Performance Indicators (KPIs) for measuring the company's performance. It is evaluated by customer feedback and is essential for identifying problem areas and implementing corrective actions. CES started working on a special report to track trends in customer satisfaction after realising its crucial importance. The main objective was to carefully examine customer feedback and rating data to pinpoint specific areas that needed improvement in the overall customer experience.

This comprehensive report was designed with Power BI, applying the dashboard creation process steps available in Figure 12.

The first step was to gather requirements and compile data of information relevant to the report's end users. This step ensured that the report would be customised to satisfy the particular needs of CES stakeholders.

The ideation phase started by drawing inspiration from current KPI history reports in other categories. This stage concentrated on organising the report to convey historical customer satisfaction data.

Fortunately, CES's data infrastructure already contained the information needed for this report, eliminating the need for Extract, Transform, and Load (ETL) procedures from outside data sources. This made it possible to develop reports more efficiently.

The CES Customer Satisfaction History Report, shown in Figure 15, is the result of this effort. This interactive dashboard provides insightful information about how clients view CES's performance over time.

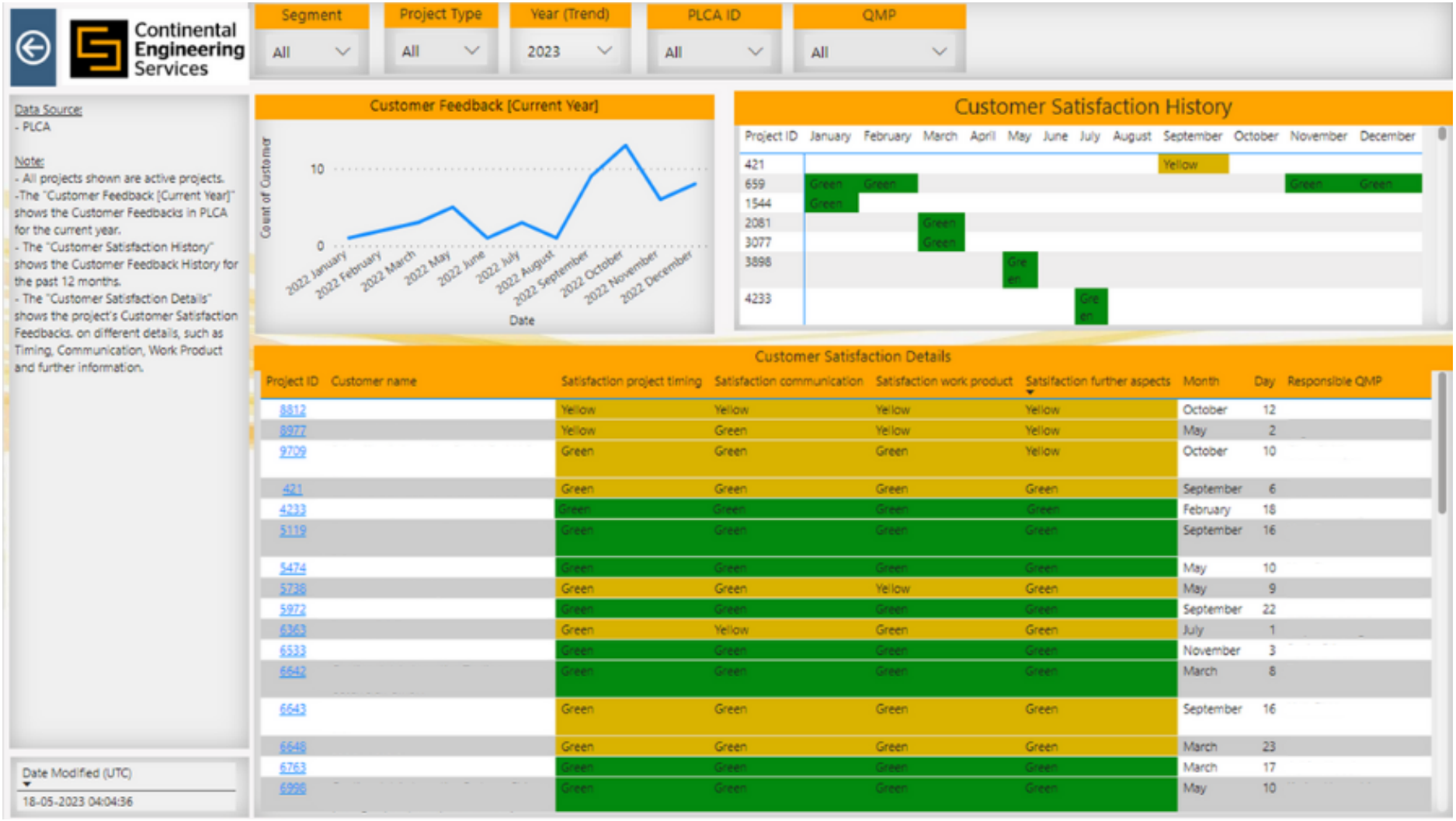


Figure 15: CES Customer Satisfaction History Report.

The Customer Satisfaction History Report offers a complex view of CES's and its clients' interactions. The management team can proactively implement customer-centric improvement strategies by closely monitoring this report. Key advantages and learnings include:

Identification of Trends: The report aids in the identification of customer satisfaction trends, enabling CES to keep up with changing consumer preferences and expectations.

Pattern Recognition: By identifying patterns in customer reviews and ratings, targeted strategies to improve the customer experience can be developed.

Sentiment analysis: Incorporated into the report to help readers understand their customers' attitudes, whether positive, negative, or neutral.

Historical Benchmarking: The report's historical data is used as a standard for gauging progress and assessing the results of measures taken to address customer complaints.

Data-Driven Decision-Making: CES can now respond to customer complaints and feedback with informed, data-driven decisions, resulting in more effective and efficient increases in customer satisfaction.

The Customer Satisfaction History Report is an essential tool that enables CES to take strategic, client-centred decisions. It is a helpful tool for tracking development, resolving issues, and improving customer experience.

4.1.2 Correlation Analysis of KPIs

Project execution success and overall operational excellence depend on effective project performance monitoring. The evaluation of project planning and execution depends heavily on key quality metrics like FPY and PQSR. However, the accuracy of these metrics can be impacted by inconsistencies brought on by disparate interpretations and reporting schedules. This thesis explores the relationship between First Pass Yield (FPY) and Project Quality Status Report (PQSR) and offers suggestions for improving their alignment and interpretation.

FPY evaluates the "First time right, on-time" execution of project development stages, emphasising their timely release, reducing customer escalations and improving the

project's overall quality. PQSR offers recurring quality status reports that cover management priority areas, quality risks, and life cycle status. The evaluation of project planning and execution depends on both metrics.

For data mining and analysis, the CRISP-DM framework, a widely used methodology, provides a structure for this study. The iterative cycle of the model makes it easier to analyse the relationships between FPY and PQSR metrics systematically. The correlation between these metrics can be understood through statistical and exploratory R programming language analysis.

Data analysis from the FPY metric reveals generally successful project execution. Comparatively, PQSR data shows a sizable amount of non-green reporting, highlighting areas of concern. It is more difficult to determine their correlation because each metric has different reporting times.

The relationship between FPY and PQSR was clarified through statistical and exploratory analysis using the R programming language. While some insights are obtained, more research is necessary due to the complexity of the different reporting timeframes.

FPY and PQSR reporting results are inconsistent and vary due to different interpretive approaches. It is advised that efforts be made to synchronise reporting timeframes for these metrics to address these issues. Accurate correlation analysis and interpretation will be made more accessible by this alignment.

Project performance evaluation can be significantly improved by improving the alignment and interpretation of quality metrics. Streamlining reporting processes and enhancing interpretation procedures will allow for more accurate analysis and ongoing improvement in CES's operations.

The significance of accurate analysis and reporting in assessing project planning and execution is stressed in this master's thesis. This study highlights the need for synchronised reporting timeframes and enhanced interpretation procedures by examining the interrelationship between FPY and PQSR. The suggested strategies seek to improve operational effectiveness, encourage constant development, and support the overall project success within CES.

Upon exploring FPY data, it was evident that project execution was generally successful. However, the PQSR data showed a significant amount of unexplained non-green reporting, highlighting areas of concern. It was found that both KPIs were based on different people's interpretations, which could have generated inconsistent and varying results.

The following dashboards (Figure 16 and Figure 17) include the statistical distribution of the status reports of both KPIs in the last year, it is essential to mention that each gate stated in the FPY Report is equivalent to a stage of the projects analysed.

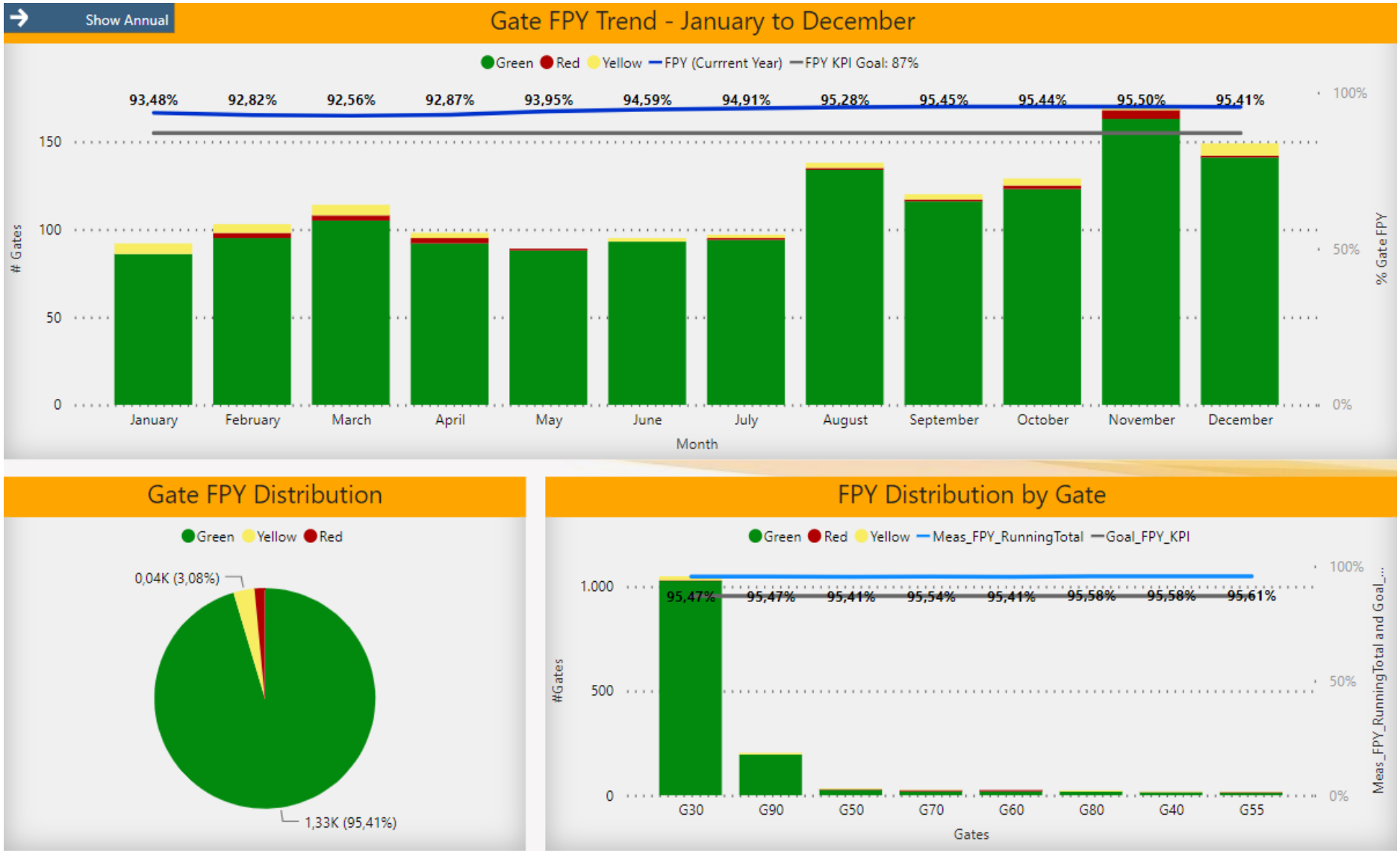


Figure 16: FPY Status Statistical Distribution Power BI Report.

Figure 17: PQSR Status Statistical Distribution Power BI Report.

Given these results, it is essential to carry out additional research to address the discrepancies and potential biases resulting from different interpretive approaches. To enable more accurate analyses and ensure a more explicit representation of the projects' quality status, efforts should be made to synchronise the reporting timeframes of both metrics. CES can improve the effectiveness of these KPIs in evaluating project planning and execution and promote continuous improvement throughout their operations by streamlining the reporting processes and improving the interpretation procedures.

4.2 Reports and Tools Automation

The study's second goal is to implement solutions to allow the automation of the generated reports. The subsequent actions helped to achieve this goal.

Through the automation of data refresh in the Power BI platform, there is a significant potential to improve operational efficiency within the digitalised QMS. With the help of this initiative, the dashboards and reports will always reflect the most recent data without requiring manual intervention. The present restrictions result from a time-constrained internship and knowledge gaps in sophisticated databases and programming. The advantages of this automation, though, should not be understated.

The company can ensure stakeholders can always access real-time insights by setting up scheduled data extraction and refresh mechanisms. This makes it easier to make quick, well-informed decisions, which is essential in the fast-paced business environment. The effective implementation of automated data refresh is consistent with the overarching goals of raising customer satisfaction, enhancing the quality of products, and enhancing overall organisational performance.

Leveraging Power BI's Natural Language Q&A feature represents another promising area for improvement. This feature could fundamentally alter how users interact with our QMS's data. Because data manipulation and query writing are currently so complex, users may encounter difficulties when attempting to extract insights. This feature can streamline and democratise data access by turning on the Natural Language Q&A.

This functionality will enable dashboard users to query the data in plain English without the need for specialised technical knowledge. This improves user-friendliness while also encouraging more significant organisational data usage. We predict this will increase customer satisfaction, product quality, and overall organisational performance.

In conclusion, the digitalised QMS at CES presents significant opportunities for improvement through automation and improved data interaction. It is impossible to ignore

the potential advantages, such as real-time insights and user-friendly data access, despite the difficulties brought on by a lack of time and specific skill gaps. The practical implementation of these improvement strategies is consistent with our overarching objectives of achieving operational excellence and generating favourable results across many areas of the organisation.

4.3 Reports and Tools Maintenance

The following tasks help support the final objective, highlighting the importance of ongoing maintenance of the created reports.

The constant improvement and adaptation of data visualisation tools, such as dashboards, are necessary for effective decision-making in today's dynamic business environment. In order to support more thorough and informed decision-making, this research examines methods for ensuring the relevance and accuracy of these tools. This thesis focuses on the creation and upkeep of dashboards to enhance user experience, which will ultimately lead to greater engagement with the Quality Management System (QMS) and an organisational culture of continuous improvement.

A multifaceted strategy has been adopted to achieve these goals. This strategy includes updating interactive features, particularly tooltips, and updating dashboard descriptions as well as how data is presented. These actions were taken to improve the dashboards' clarity, relevance, and usability. Aside from that, metrics for engagement and user feedback were gathered to gauge the results of these upgrades.

To accurately reflect the content and purpose of each dashboard, dashboard descriptions needed to be updated as the first step in this improvement process. User comprehension and navigation are made more accessible by concise and clear descriptions. These changes were made to the dashboards to maintain alignment with organisational goals in response to shifting business needs.

Data presentation was improved to increase the dashboards' relevance. This required thoroughly examining the data elements' structure and visual representation. It was intended to present data in a way that maximised its value as information, making it more straightforward for users to derive insights and make wise decisions.

Power BI's interactive features, particularly tooltips, have been updated to give users more precise and pertinent information. This improvement was made to help users better understand the data shown on the dashboards by focusing on the information. We sought to improve the user experience overall by customising tooltips to user needs.

The company displayed a commitment to providing accurate and reliable information for decision-making by pledging regular maintenance and improvements of tools and reports. A culture of continuous development and quality improvement is promoted by this proactive approach, which encourages the early detection and remediation of quality issues.

The importance of continuously improving and adapting dashboards to meet changing business needs is highlighted in this master's thesis conclusion. The methods described here, which include updating the dashboard description, improving the data presentation, and optimising interactive features, have proven successful in enhancing user experience and encouraging engagement within the QMS. As a result, the organisation's decision-making is improved, and a culture of continuous improvement and proactive quality issue resolution is fostered.

CHAPTER 5

CONCLUSIONS

The conclusions reached during the implementation of the developed project will be presented in this chapter. In addition, potential improvements to the current system and future perspectives will be mentioned.

5.1 ANALYSIS AND EVALUATION OF THE PROJECT

In conclusion, introducing Industry 4.0 has given companies a game-changing opportunity for quality management. The business can achieve real-time monitoring, automate quality control, and facilitate predictive maintenance by implementing intelligent technologies. These developments enable the companies to deal with quality issues proactively and significantly raise client satisfaction. By exploiting enormous amounts of data and unlocking previously unfathomable insights, embracing Industry 4.0 enables the company to remain competitive in the ever-evolving market.

However, it is critical to recognise this study's limitations. A significant barrier to fully exploring and applying some technological solutions was the lack of expertise in databases and programming languages. Future training programs that improve technical capabilities should be considered to utilise Industry 4.0's potential for quality management fully.

The steps taken into consideration in the development of this dissertation must be repeated because this is a continuous process for continuous improvement. Its findings open the door for further development and innovation at the company providing automotive engineering services by encouraging a culture of constant innovation and flexibility in the face of new technological developments.

5.2 FUTURE WORK

Several critical focus areas have been identified for further development as the automotive engineering services company continues its journey towards enhancing the digitalised Quality Management System and embracing Industry 4.0. Enhancing quality management procedures and raising customer satisfaction levels in these areas offers exciting new opportunities.

A thorough gap analysis of CES's current quality metrics should be conducted to promote continuous improvement in quality management. The current set of performance and quality indicators could be carefully analysed compared to industry standards and best practices. The business can improve its quality metrics framework and guarantee alignment with its strategic objectives by identifying gaps and potential areas for improvement.

By gaining valuable insight into potential areas that need more focus and attention, the gap analysis will enable CES to allocate resources to the KPIs with the most prominent effects on product quality and customer satisfaction. This data-driven strategy will promote a culture of quality and data-based decision-making.

To achieve data accuracy and efficiency, CES could also conduct an extensive study to find and address duplicate and unnecessary data reporting to databases. The inability of the business to make informed decisions may be hampered by duplicate data entries, which can result in discrepancies and inaccuracies in quality reports. The streamlining of data collection and making sure that only pertinent and necessary data is recorded and stored in databases will lead to the minimisation of data redundancy and optimising storage resources, these data restriction protocols will help maintain a tidy and organised database.

CES should set up alerts based on predefined quality goals to improve real-time monitoring and proactive quality management. The system can automatically send alerts when critical quality metrics deviate from predetermined thresholds. With this proactive approach, the business can spot quality problems as they arise and act swiftly to fix them. Setting up alerts for quality metrics like Cycle Time, FPY, and Customer Satisfaction will allow the company to act quickly to stop potential flaws, delays, or customer dissatisfaction. CES can use advanced analytics and machine learning algorithms to build dynamic alert systems that adjust to shifting operational conditions and continuously raise the quality of alerts.

References

Alaidaros, Hamzah, and Mazni Omar. 2018. "Software Project Management Approaches for Monitoring Work-In-Progress: A Review." https://www.researchgate.net/publication/324151349.

Almeida da Silva, Rafael. 2022. "Review and Digitisation of the Quality Management System and Continuous Improvement."

Al-Noukari, M., and W. Al-Hussan. 2008. "Using Data Mining Techniques for Predicting Future Car Market Demand; DCX Case Study." In *3rd International Conference on Information and Communication Technologies: From Theory to Applications*, 1–5. IEEE.

Atlassian. 2023. "Confluence Software." https://www.atlassian.com/software/confluence.

Atlassian. 2023. "Jira Software." https://www.atlassian.com/br/software/jira.

Awasthi, A. 2012. "Business Intelligence: Concepts, Components, Techniques and Benefits." *Asian Journal of Management* 3 (4): 196–203.

Badawy, Mohammed, A.A. Abd El-Aziz, Amira M. Idress, Hesham Hefny, and Shrouk Hossam. 2016. "A Survey on Exploring Key Performance Indicators." *Future Computing and Informatics Journal* 1 (1–2): 47–52. https://doi.org/10.1016/j.fcij.2016.04.001.

Behutiye, Woubshet, Pilar Rodríguez, Markku Oivo, Sanja Aaramaa, Jari Partanen, and Antonin Abhervé. 2022. "Towards Optimal Quality Requirement Documentation in Agile Software Development: A Multiple Case Study." *Journal of Systems and Software* 183 (January). https://doi.org/10.1016/j.jss.2021.111112.

Brooks, Aaron. 2023. "Best Analytics and Business Intelligence Platforms." January 9, 2023. Best analytics and business intelligence platforms. https://www.ventureharbour.com/ best-analytics-business-intelligence-platforms/.

Burkacky, Ondrej, Johannes Deichmann, Stuttgart Jan, and Paul Stein. 2019. "Automotive Software and Electronics 2030."

CES. "Continental Engineering Services." 2023. Accessed June 22, 2023. https://conti-engineering.com/.

Chaudhuri, S., U. Dayal, and V. Narasayya. 2011. "An Overview of Business Intelligence Technology." Communications of the ACM 54 (8): 88–89.

Colpani, Rogério. (2019). Mineração de Dados Educacionais: um estudo da evasão no ensino médio com base nos indicadores do Censo Escolar. Informática na educação: teoria & prática.

Continental. 2023. "Continental." 2023. https://www.continental.com/en/.

Damij, Nadja, and Talib Damij. 2021. "An Approach to Optimising Kanban Board Workflow and Shortening the Project Management Plan." IEEE Transactions on Engineering Management. https://doi.org/10.1109/TEM.2021.3120984.

Datapine. 2019. "Introduction to the Basic Business Intelligence Concepts." 2019. https://www. datapine.com/.

Delloite Insights. 2020. "Industry 4.0 in Automotive Digitizing the End-to-End Automotive Value Chain Steering into Industry 4.0 in the Automotive Sector."

Dieguez, Teresa, Luís Pinto Ferreira, F. J.G. Silva, and Benny Tjahjono. 2020. "Open Innovation and Sustainable Development through Industry-Academia Collaboration: A Case Study of Automotive Sector." In Procedia Manufacturing, 51:1773–78. Elsevier B.V. https://doi.org/10.1016/j.promfg.2020.10.246.

Gheorghe, A. M., I. D. Gheorghe, and I. L. Iatan. 2020. "Agile Software Development." Informatica Economica 24 (2).

Giacosa, Elisa, Francesca Culasso, and Edoardo Crocco. 2022. "Customer Agility in the Modern Automotive Sector: How Lead Management Shapes Agile Digital Companies." Technological Forecasting and Social Change 175 (February). https://doi.org/10.1016/j.techfore.2021.121362.

Gruszka, Józef, and Agnieszka Misztal. 2017. "The New IATF 16949:2016 Standard in the Automotive Supply Chain." Research in Logistics and Production 7 (4): 311–18. https://doi.org/10.21008/j.2083-4950.2017.7.4.3.

Haokip, FR. Paul Lelen. 2021. "The Fourth Industrial Revolution and the Probable Future of Learning." Https://Imphalreviews.in/the-Fourth-Industrial-Revolution-and-the-Probable-Future-of-Learning/. October 2, 2021.

“How AS9145 Impacts Quoting and New Business.” Plexus International, April 5, 2022. https://plexusintl.com/us/blog/how-as9145-impacts-quoting-and-new-business/.

Inmon, W. H. 2005. "Building the Data Warehouse. Timely, Practical, Reliable." Wiley.

Klašnja-Milićević, Aleksandra, Mirjana Ivanović, and Zoran Budimac. 2017. "Data Science in Education: Big Data and Learning Analytics." In Computer Applications in Engineering Education, 1066–78.

Kintz, Maximilien, Monika Kochanowski, and Falko Koetter. 2017. "Creating User-Specific Business Process Monitoring Dashboards with a Model-Driven Approach." In *International Conference on Model-Driven Engineering and Software Development*, edited by M. Kintz, M. Kochanowski, and F. Koetter, 353–61. SciTePress.

Melnyk, S. A., D. M. Stewart, and M. Swink. 2004. "Metrics and Performance Measurement in Operations Management: Dealing with the Metrics Maze "." Journal of Operations Management 22: 209–17.

Mircea, E. 2019. "Project Management Using Agile Frameworks." Academy of Economic Studies. Economy Informatics 19 (4).

Muhammad, G., J. Ibrahim, Z. Bhatti, and A. Waqas. 2014. "Business Intelligence as a Knowledge Management Tool in Providing Financial Consultancy Services." Business Intelligence as a Knowledge Management Tool in Providing Financial Consultancy Services. 2 (2): 26–32.

Noureldin, M., A. Ghalwash, L. Abd-Ellatif, and M. ElGazzar. 2022. "Blending Agile Methodologies to Support Automotive SPICE Compliance." Journal of Software: Evolution and Process 34 (1).

Ong, I. L., P. H. Siew, and S. F. Wong. 2011. "A Five-Layered Business Intelligence Architecture." Communications of the IBIMA, 1–11.

Papulová, Zuzana, Andrea Gažová, and Lubomír Šufliarský. 2022. "Implementation of Automation Technologies of Industry 4.0 in Automotive Manufacturing Companies," 2022. https://doi.org/10.1016/j.procs.2022.01.350.

Parmenter, David. 2015. Key Performance Indicators: Developing, Implementing, and Using Winning KPIs. John Wiley & Sons.

Pauwels, K. 2009. "Dashboards as a Service: Why, What, How, and What Research Is Needed?" Journal of Service Research 12 (2): 175–89.

Popkova, Elena G, · Yulia, V Ragulina, and Aleksei V Bogoviz Editors. 2018. "Industry 4.0: Industrial of the 21st." http://www.springer.com/series/13304.

PwC. 2016. "Industry 4.0: Building Digital Enterprise." www.pwc.com/industry40.

Saihi, Afef, Mahmoud Awad, and Mohamed Ben-Daya. 2023. "Quality 4.0: Leveraging Industry 4.0 Technologies to Improve Quality Management Practices – a Systematic Review." International Journal of Quality and Reliability Management. Emerald Publishing. https://doi.org/10.1108/IJQRM-09-2021-0305.

Sameh, S., and S. EL-Toukhi. 2020. "Application of Mutually Integrated International Standards (A-SPICE PAM 3.1 & IATF 16949/2016)." In Systems, Software and Services Process Improvement: 27th European Conference, EuroSPI 2020, 673–83. Düsseldorf, Germany: Springer International Publishing.

Sansom, Carolyn. 2022. "Six Key Skills for Turning Data into Insight." March 28, 2022. https://www.grantthornton.co.uk/insights/six-key-skills-for-turning-data-into-insight/.

Sen, A., and A. P. Sinha. 2005. "A Comparison of Data Warehousing Methodologies." Communications of the ACM 48 (3): 79–84.

Singh, Jagmeet, I. P.S. Ahuja, Harwinder Singh, and Amandeep Singh. 2022. "Development and Implementation of Autonomous Quality Management System (AQMS) in an Automotive Manufacturing Using Quality 4.0 Concept– A Case Study." Computers and Industrial Engineering 168 (June). https://doi.org/10.1016/j.cie.2022.108121.

Smaya, Haya. 2022. "The Influence of Big Data Analytics in the Industry." Open Access Library Journal 9.2: 1–12.

Valladares Montemayor, Halia M., and Rayyan Hamza Chanda. 2023. "Automotive Industry's Circularity Applications and Industry 4.0."Environmental Challenges 12 (August). https://doi.org/10.1016/j.envc.2023.100725.

Wang, Jianwen, Abdullah Hisam Omar, Fahad M. Alotaibi, Yousef Ibrahim Daradkeh, and Sara A. Althubiti. 2022. "Business Intelligence Ability to Enhance Organisational Performance and Performance Evaluation Capabilities by Improving Data Mining Systems for Competitive Advantage." Information Processing and Management 59 (6). https://doi.org/10.1016/j.ipm.2022.103075.

Watson, H. J. 2009. "Tutorial: Business Intelligence – Past, Present, and Future." Communications of the Association for Information Systems 25 (11): 487–510.

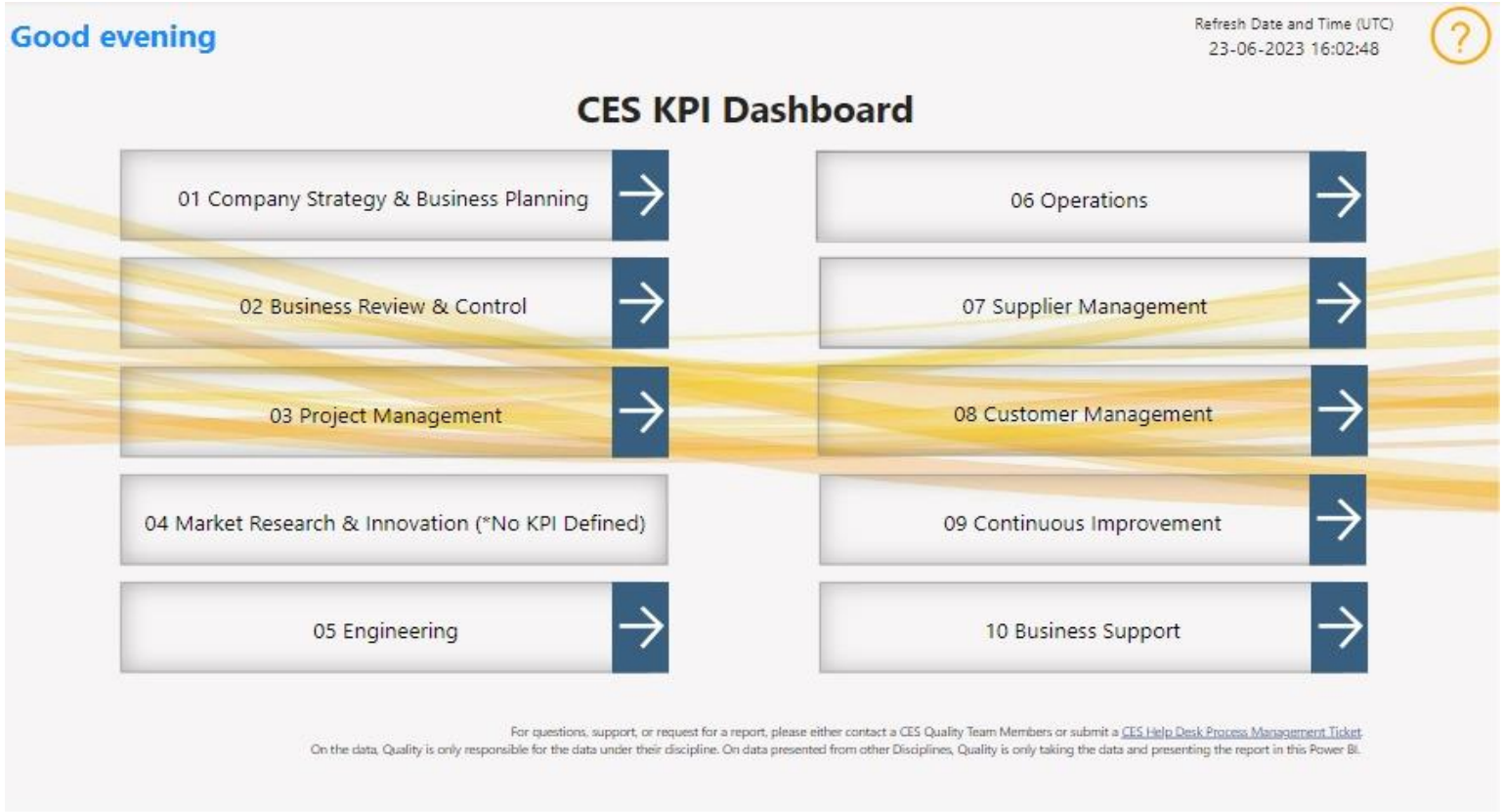
Watson, H. J. 2014. "Tutorial: Big Data Analytics: Concepts, Technologies, and Applications." Communications of the Association for Information Systems 34 (65).

Weflen, Eric, Cameron A. MacKenzie, and Iris V. Rivero. 2022. "An Influence Diagram Approach to Automating Lead Time Estimation in Agile Kanban Project Management." Expert Systems with Applications 187 (January). https://doi.org/10.1016/j.eswa.2021.115866.

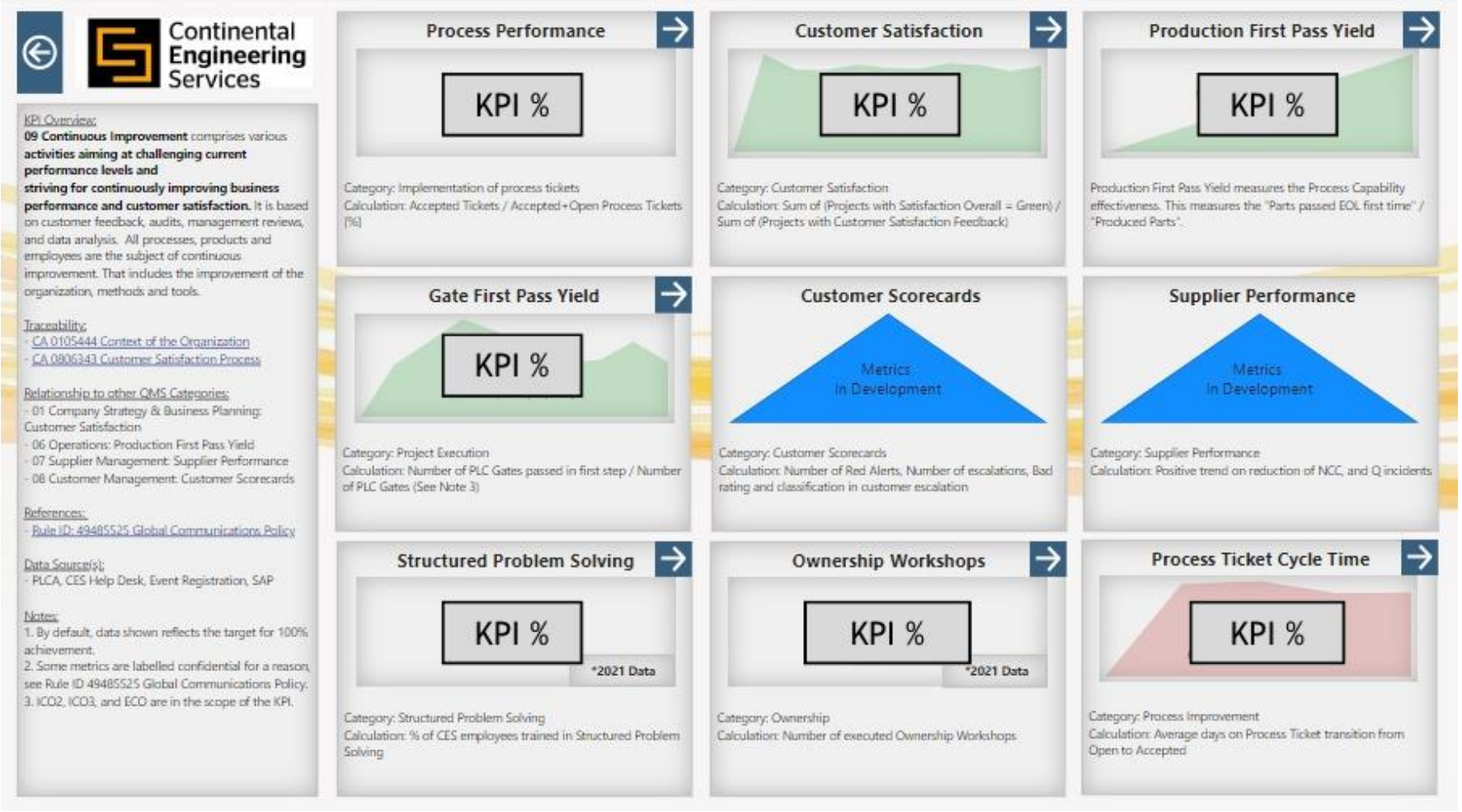
Wu, Lei, and Houari Sahraoui. 2004. "Supporting Web Collaboration for Cooperative Software Development."

APPENDIX 1 – REPORT PAGES FROM CES QUALITY POWER BI DASHBOARD

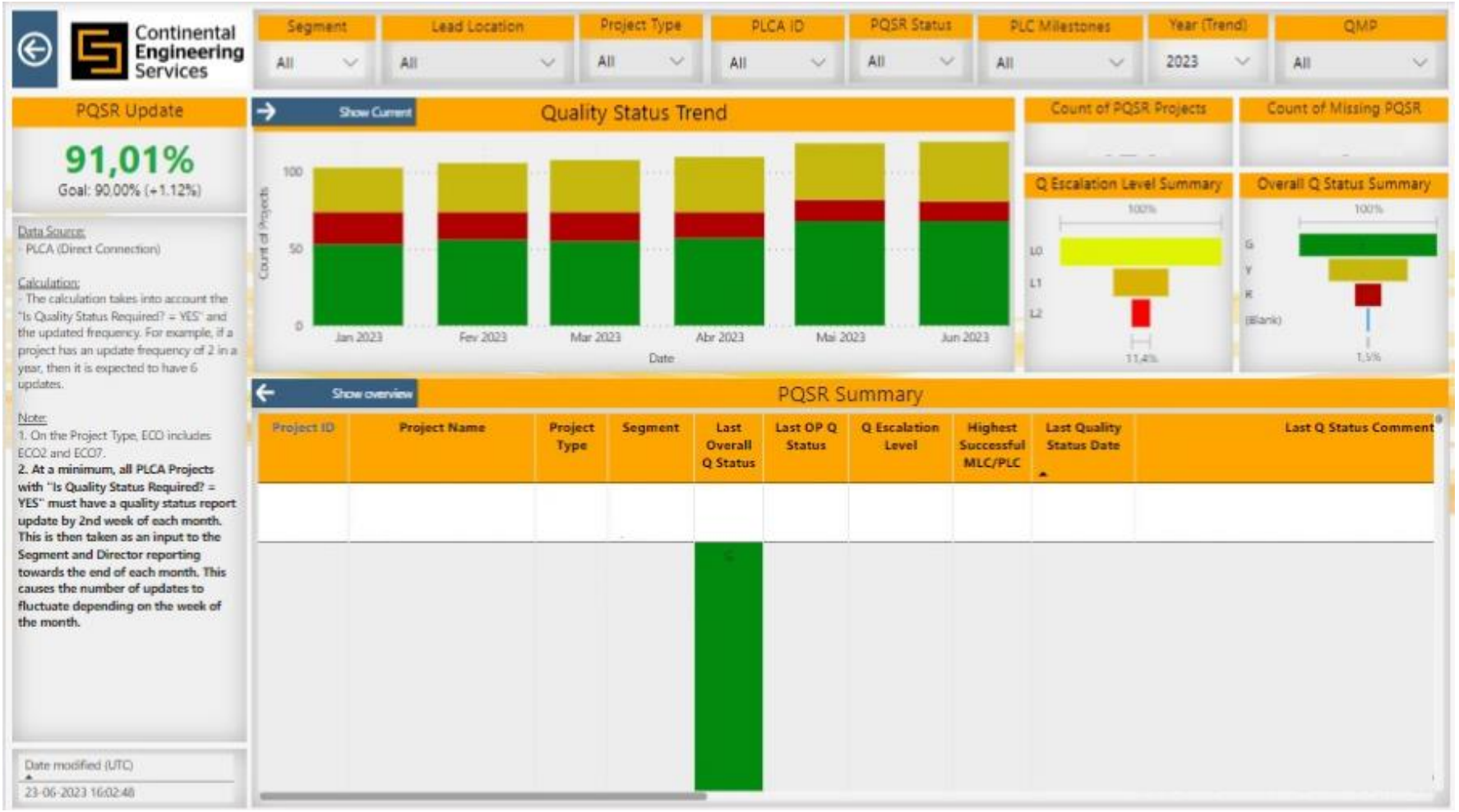
Power BI - Summary Dashboard



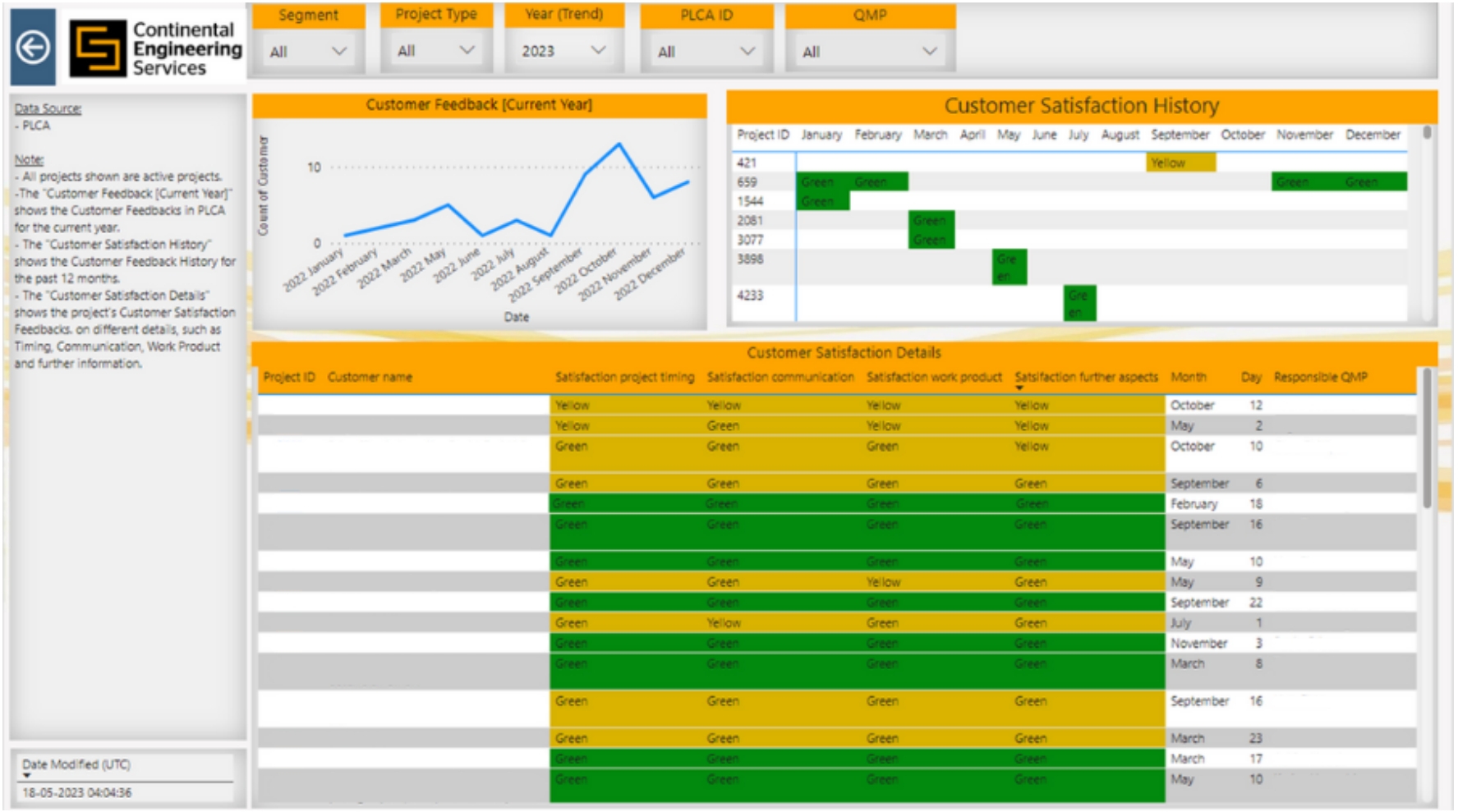
Power BI - QMS Category Dashboard Example



Power BI - Quality KPI Dashboard Example 1



Power BI - Quality KPI Dashboard Example 2



Power BI - KPI Tooltip Example