UNIVERSITY OF LJUBLJANA
SCHOOL OF ECONOMICS AND BUSINESS

MASTER'S THESIS

MERGING MULTIPLE BUSINESS INTELLIGENCE SOFTWARE TO PROVIDE A UNIFIED ENVIRONMENT: A SELECTED COMPANY CASE

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

API	Application Programming Interface
AI	Artificial Intelligence
BA	Business Analytics
BARC	Business Application Research Center
BI	Business Intelligence
BIA	Business Intelligence & Analytics
CRM	Customer Relationship Management
DAT	Data and Technology
DSR	Design Science Research
DSS	Decision Support System
DWC	SAP Data Warehouse Cloud
EDW	Enterprise Data Warehouse
EIS	Executive Information System
ERP	Enterprise Resource Planning
ETL	Extract, Transform, Load
IBCS	International Business Communication Standards
IoT	Internet of Things
IS	Information System
MIS	Management Information System
MSS	Management Support System
OLAP	Online Analytical Processing
SAC	SAP Analytics Cloud
SCM	Supply Chain Management
SQL	Structured Query Language
TAM	Technology Acceptance Model
UEQ	User Experience Questionnaire
URL	Uniform Resource Locator

INTRODUCTION

In today's world, new business concepts are having a massive impact on the development of the global economy. New technologies are making their way into the market, forcing companies in various industries to compete with their competitors and maintain their position as industry leaders (Sudhakaran, 2021). Indeed, the BARC study, which surveyed some 2,400 Business Intelligence (hereafter: BI) experts on the most important BI trends in 2022, shows that companies are trying to position themselves well for the long term and are working on the fundamentals of their data usage. However, the study also showed that companies are trying to address the root causes of their challenges (e.g., data quality) and tackle the holistic establishment of a data-driven culture (Business Application Research Center, 2022). In the course of the digital transformation, digital processes in companies are generating ever-greater volumes of data due to technological developments. Especially for successful business management and making the right decisions, detailed, deep insights into the many different processes are required. The days of making business decisions based on experience and intuition have given way to information-based decision-making, which is critical to managing the business at every stage and provides management with a holistic view of the company's performance (Ungureanu, 2021). The generation, careful analysis and use of data are the basis for developing strategies at every stage for companies in all industries around the world. In this process, many organizations face the challenge of collecting, managing and evaluating large volumes of data (Niu, Ying, Yang, Bao & Sivaparthipan, 2021). BI offers a suitable approach to solving these problems. BI software enables companies to accelerate and improve decision-making processes, streamline internal business processes, increase operational efficiency, generate new revenue and gain a competitive advantage over competitors (Işık, Jones & Sidorova, 2013). BI also makes it possible to identify patterns and trends in data and extract meaningful information. Moreover, especially in the context of Industry 4.0, Big Data and the Internet of Things (hereafter: IoT), the analytical component is becoming increasingly important (Gandhil & Pruthi, 2020).

However, there is often a gap between the information management needs for early detection and proper decision-making, and thus to ensure business success and the amount of data collected by business units (Zafary, 2020). When departments are not provided with flexible and simple tools, they often tend to develop their own reporting solutions based on Excel or even "ready-to-use" tools without the support and approval of the IT department (Quack, 2012). This often leads to heterogeneous BI system landscapes with multiple non-integrated data sources (data marts and data warehouses) and different reporting tools in which the data is stored independently and possibly even redundantly, resulting in high costs for care and maintenance (Business Intelligence Consulting, 2016). Furthermore, even if the data basis is the same, sometimes there are different business logics in the frontend reports that lead to different results and are therefore untransparent. This is where combining multiple BI tools into an integrated dashboard can help maintain preferences when selecting such software and support all members of an organization to move from isolated and project-oriented data use to an entirely data-driven culture that provides the foundation for adequate strategic decision-making. It is to be shown how different BI tools connected to a data warehouse can be shared in a modeling tool. In this way, all relevant information in the company should be available at the right time, in the right place and in a suitable form for the respective employee.

BI dashboards enable companies to analyze complex data from databases and provide information for decision-making. However, prior access to the data is required to gain insight into the data. Many companies have a lot of data on every aspect of their business, distributed across the enterprise and stored in various systems, making access a major challenge. Due to the widespread availability of BI software, varying preferences, and the different benefits of these tools, companies are losing the ability to get a unified view of their business by using different software. As a result, many try to switch to a particular BI software that suits their business needs best, but this negates the benefits of the various offerings. This raises the question of linking multiple BI software that integrates all data insights across the enterprise based on real-time data analytics and enables strategic discussions across all business decisions. Thus, this work aims to provide a set of guidelines to companies considering merging different BI software to ensure successful integration into a unified BI environment as a basis for strategic decisions.

Given the purpose, the goal of this master thesis is to develop a cascading dashboard concept based on SAP Analytics Cloud (hereafter: SAC) and Tableau and to evaluate its feasibility and acceptance. To make the goal more concrete, the first sub-goal is to develop the theoretical foundations of business intelligence and dashboards that will serve as the basis for providing the topic on which the research is built. This will also determine the selection of BI software for implementing the use case. The second sub-goal is to develop an integrated dashboard concept by combining multiple BI tools in the context of a case study. The dashboard implementation focuses on successful integration into a unified BI environment as a foundation for strategic decision-making. The third sub-goal is to evaluate the developed prototype through user testing and interviews to verify its relevance and extend it with practical insights. The final sub-goal is to produce a guideline and business value analysis for further practical applications and projects.

The master thesis is written in cooperation with MHP Management- und IT-Beratung GmbH, a German consulting company. A Design Science Research (hereafter: DSR) approach is used as the overarching research methodology in this thesis to develop the design artifact. A case study using the DSR approach is applied as the evaluation method. Multiple data collection approaches are taken to determine the case study's results, beginning with a survey as a quantitative data source based on the mockup, followed by an expert interview as a qualitative data source based on the prototype. The incrementally collected data and its incorporation into the next phase will allow for a detailed analysis of the results, which will serve as a basis for theory building, provide a theoretical and practical contribution to the process, and allow for an answer to the research question.

Hence, the master thesis is divided into a theoretical and a practical part. In the theoretical part, the topic of business intelligence is presented in its main features, data is introduced as a success factor and decision support is presented as a value proposition. Furthermore, the basics of dashboards are discussed, and BI software tools are presented in their capabilities. In the practical part, a case study is developed, the results of the conducted study are presented, the findings are discussed, and conclusions are drawn.

1 THEORETICAL FOUNDATIONS

The theoretical part of the work is based on a literature review of current databases, books, scientific papers, research papers, websites, journals, and e-books, relying on secondary sources. To ensure a common thread in the work, three works of literature, namely Baars & Kemper (2021), Linden (2015) and Skyrius (2021) are used for the study. In addition, keyword searches in scientifically accepted electronic databases use references to related articles as another source of identification. To ensure the required quality of the selected literature, mainly high-quality research and professional journals, as well as scientific papers, are used. In addition, selected areas of study will also utilize research papers and studies that address current trends and developments in the context of business intelligence and dashboards, which represent the necessary basic understanding of the work.

1.1 Business Intelligence

The different views on the term BI originate from the so-called management support systems (hereafter: MSS), which have been the umbrella term for analytical information systems that have already supported specialists and managers in their tasks with IT support since the 1960s. The underlying reason for this development was a large amount of data, which for the first time created a need for automatically processed data to support management. The activities related to all management levels, i.e., both top management, which primarily deals with strategic tasks (strategic information systems), and middle and lower management, which primarily performs operational management tasks (operational information systems). Scott Morton (1983), one of the key proponents of this approach, defined the term MSS as "the use of computers and related information technologies to support managers" (p. 5). The rapid technological development led to new forms of MSS and, thus, over the years, to a categorization of the technical expressions into so-called management information systems (MIS), decision support systems (hereafter: DSS) and executive information systems (EIS). In the further course, problem- and decision-relevant information was integrated via a customizable user interface through timely data provision. And since the mid-1990s, the term "Business Intelligence" has thus gained acceptance and largely replaced the older MSS, especially in corporate practice. Although BI can fundamentally be considered a subset of

DSS, over time, it has lost its connection to the DSS foundational literature and offers the promise of turning more data into more profound insights to improve intelligence and decision-making (Phillips-Wren, Daly & Burstein, 2021). The term can be traced back primarily to considerations by the Gartner Group. The 1996 report states: "By 2000, Information Democracy will emerge in forward-thinking enterprises, with Business Intelligence information and applications available broadly to employees, consultants, customers, suppliers, and the public. The key to thriving in a competitive marketplace is staying ahead of the competition. Making sound business decisions based on accurate and current information takes more than intuition. Data analysis, reporting, and query tools can help business users wade through a sea of data to synthesize valuable information from it – today these tools collectively fall into a category called "Business Intelligence"" (Baars & Kemper, 2021, p. 2). Although BI was understood as a collective term for frontend tools in earlier years, today, it has also established itself in the scientific discussion as a synonym for innovative IT solutions for corporate planning and control (Baars & Kemper, 2021; Linden, 2015).

1.1.1 Definition and classification of BI systems

BI has been considered and discussed from different perspectives in the past years. Numerous publications compiled different definitions of BI to define its most specific characteristics. These and other attempts pointed to the complexity and multidimensionality of BI and questioned whether it is even possible to create a perfect definition of BI (Linden, 2015). Some well-known attempts to define BI are listed in the following Table 1:

Table 1: Selected Business Intelligence Definitions

Azevedo, Azevedo & Hayakawa, 2021, p. 166	"Business Intelligence (BI) can be presented as an architecture, a tool, a technology, or a system that holds and stores data, analyses it using analytical tools, and provides information and/or knowledge, facilitating the production of reports, queries, and fundamentally, allowing organizations to improve their decision-making."
Wixom & Watson, 2010, p. 14	"Business intelligence is an umbrella term that is commonly used to describe the technologies, applications, and processes for gathering, storing, accessing, and analyzing data to help users make better decisions."
Atre, 2004	"I would define BI as business success realized through rapid and easy access to actionable information through timely and accurate insight into business conditions about customers, finances, and market conditions."
Rouibah & Ould-ali, 2002, p. 133	"Business intelligence is a strategic approach for systematically targeting, tracking, communicating and transforming relevant weak signs into actionable information on which strategic decision-making is based."

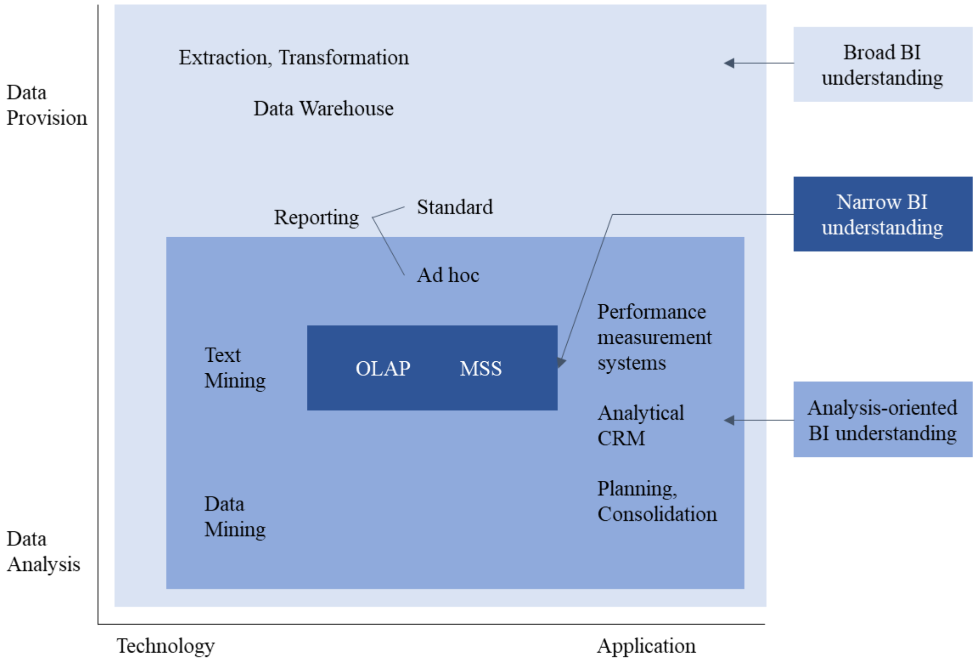
Source: Own work.

In addition, the BI specialist group of the German Informatics Society (GI) attempts to present the differences in the definition approaches according to their degree of abstraction, their orientation and their scope as in the following (Baars et al., n.d.):

1. BI as a class of IT systems,
2. BI as IT architecture,
3. BI as a collective term for technologies and concepts for decision support,
4. BI as an integrated approach to decision support,
5. BI as a knowledge generation process.

Since many attempts to define the term BI and each chosen definition remains vulnerable, it is not trivial to address the various understandings of BI. Using Gluchowski's regulatory framework, it is possible to present a structure of conceivable views from which three common interpretations have emerged, namely narrow, broader, and analysis-oriented BI, as shown in Figure 1.

Figure 1: Classification of the different views of business intelligence



Adapted from Gluchowski, Gabriel & Dittmar (2008).

A narrow understanding of the term includes only the core components that support direct decision-making. These include Online Analytical Processing (hereafter: OLAP), which will be discussed later in the master thesis, and MSS, which, as described above, are intended as report-oriented platforms for evaluating operational data and thus also for planning and control. On the other hand, the analysis-oriented understanding includes all applications in which the end-user can work directly with the system using a frontend. In addition to the OLAP and MSS systems already mentioned in the narrower understanding of BI, these also include text or data mining, planning, consolidation and performance measurements systems. BI in the broad understanding includes the two previous forms of understanding and supplements them with all components that prepare and store operational data material for information and knowledge generation, such as ETL (Extract, Transform, Load) and data warehouse, which are also briefly described in the further course of the work. In other words, this understanding of BI encompasses not only the analysis and presentation functionalities but also the systems responsible for data preparation and storage. However, these views cannot be completely separated from each other. If we look at the topic of reporting, for example, this is divided into standard and ad hoc reporting, which can be differentiated into two different areas. In summary, then, there is no single definition of the term in the current literature, but there is a great deal of agreement on what is meant by BI (Gluchowski, Gabriel & Dittmar, 2008).

Nowadays, with the emergence of technologies and new fields of application such as IoT or Industry 4.0, more sophisticated analytical approaches have gained importance with innovations such as Big Data and Cloud Computing. Accordingly, the term BI has recently been expanded to include Business Intelligence & Analytics (hereafter: BIA). BIA includes solutions for collecting historical and current data and using statistics and software to analyze raw data and gain insights for better future decisions (Baars & Kemper, 2021). However, if one compares the various definitions of BI or BIA, the characteristic of decision support crystallizes as the main feature. To ensure a uniform understanding of the term "business intelligence", the following definition approach is therefore used in this thesis.

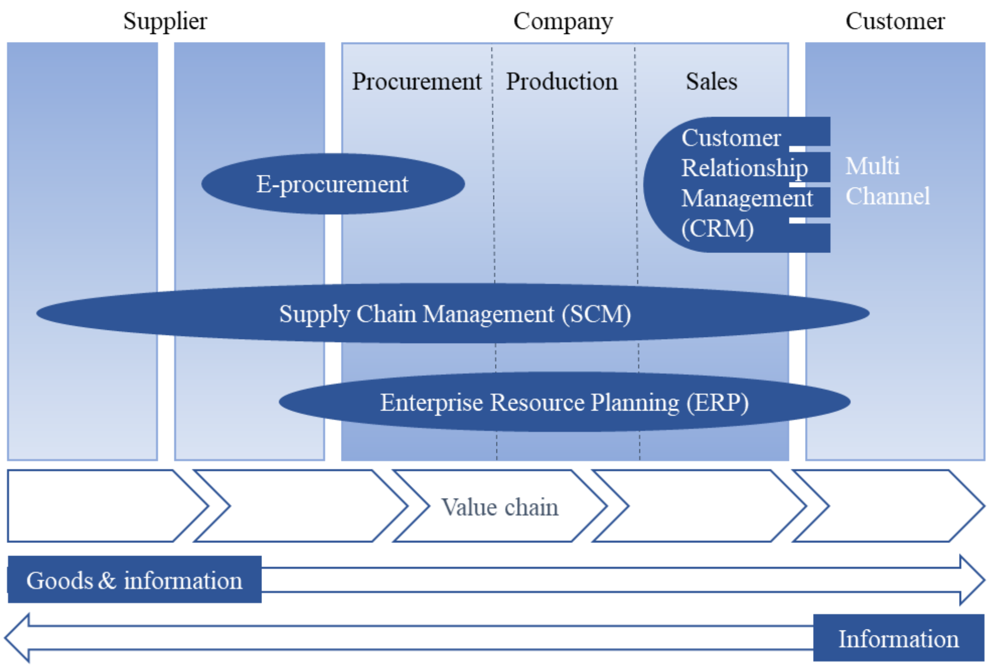
"Business intelligence is (...) an IT-based process of information generation that supports decision-making within enterprise-relevant planning, management and control" (Linden, 2015, p. 114).

The reason for using this approach lies in the descriptive properties of the definition. The intense focus on information technology and IT-based process support creates the possibility of trend-setting automated data preparation and data analysis as well as the use of unique databases and applications, such as a core data warehouse, reporting tools, or even dashboard applications. This, in turn, enables the information generation process and ensures data flow from data acquisition to data provided to data presentation. An emphasis on the target group of management can be seen in the characteristic of decision-making, which can be traced back to the fundamental area of responsibility of a specialist and manager. Finally, the characteristics of planning, management and control are the most important aspects of the definitional delimitation from a business management point of view. In particular, this is where the design and prototypical implementation of linked BI dashboards can come in, integrating all data insights from across the enterprise based on real-time data analytics and enabling strategic discussions across all business decisions (Linden, 2015).

1.1.2 BI as comprehensive system integration

The development of information systems (IS) can be seen as an effect of the continuous change in the market environment, the massive expansion of the available database and the ever-increasing internal and external requirements for consistency, speed, accuracy and transparency of operational decisions (Caserio, 2019). Above all, the IoT is one of the driving forces behind serious changes in almost all sociopolitical, economic and business areas. Digital models have already established themselves across all industries along the entire value chain. Figure 2 shows an example of typical operational application systems in the area of E-business. Here, various systems support e-business horizontally along the entire value chain. While enterprise resource planning (hereafter: ERP) systems primarily support internal activities, supply chain management (SCM) systems and customer relationship management (hereafter: CRM) systems focus on activities that ensure the economic exchange of goods and services from suppliers to customers. The diversity of systems used here highlights the need to analyze and monitor these complex systems and derive improved decision support from them (Baars & Kemper, 2021).

Figure 2: E-business and value chain

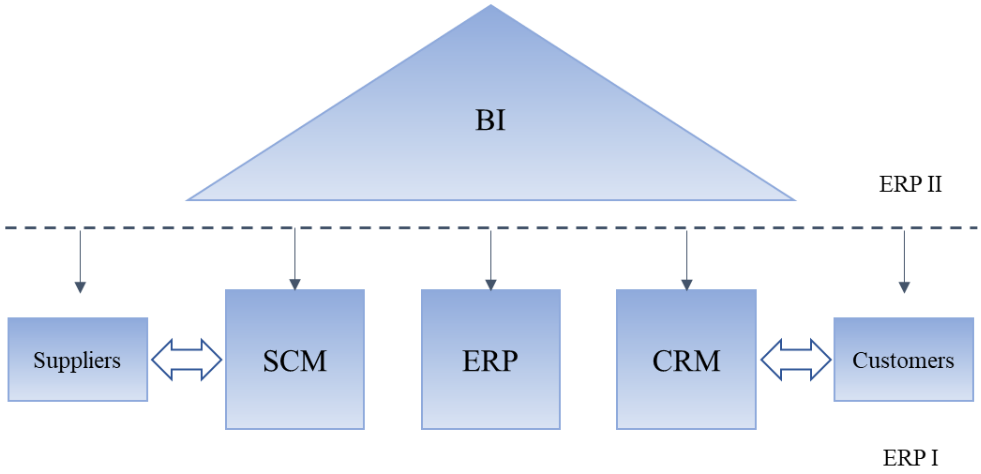


Adapted from Baars & Kemper (2021).

When talking about information systems integration, one can of course, turn to a variety of topics all related to integration and involved in an integration process, but in this thesis, the focus will be on the integration between two systems, ERP and BI. The transition from ERP to ERP II (see Figure 3), which no longer specialized in intra-company production and material requirements planning but worked across departments and companies, enabled the integration of ERP with other external business modules, including BI. According to Caserio

(2019), this transition allowed “new business tools, such as application frameworks, databases, Decision Support Systems (DSS), Business Intelligence (BI) tools and business analytics, to be integrated with ERP system, increasing considerably the business benefits” (p. 295/296). Integrating ERP and BI systems opens up a wide range of alternative IT solutions for companies and plays an important role in supporting decision-making. On the one hand, the quality of management decisions often depends on the quality of the data generated by an ERP system, which is the prerequisite for using BI. On the other hand, introducing BI systems makes ERP systems more competitive and flexible in sharing information and data to support decision-making. It can be noted that the integration of ERP with BI can lead to various potential benefits, such as increased efficiency, better decision-making, cost reduction, increased revenue, and integrated services, and even lead to a competitive advantage for enterprises, according to Caserio (2019).

Figure 3: Advanced enterprise information systems ERP II - Business Intelligence



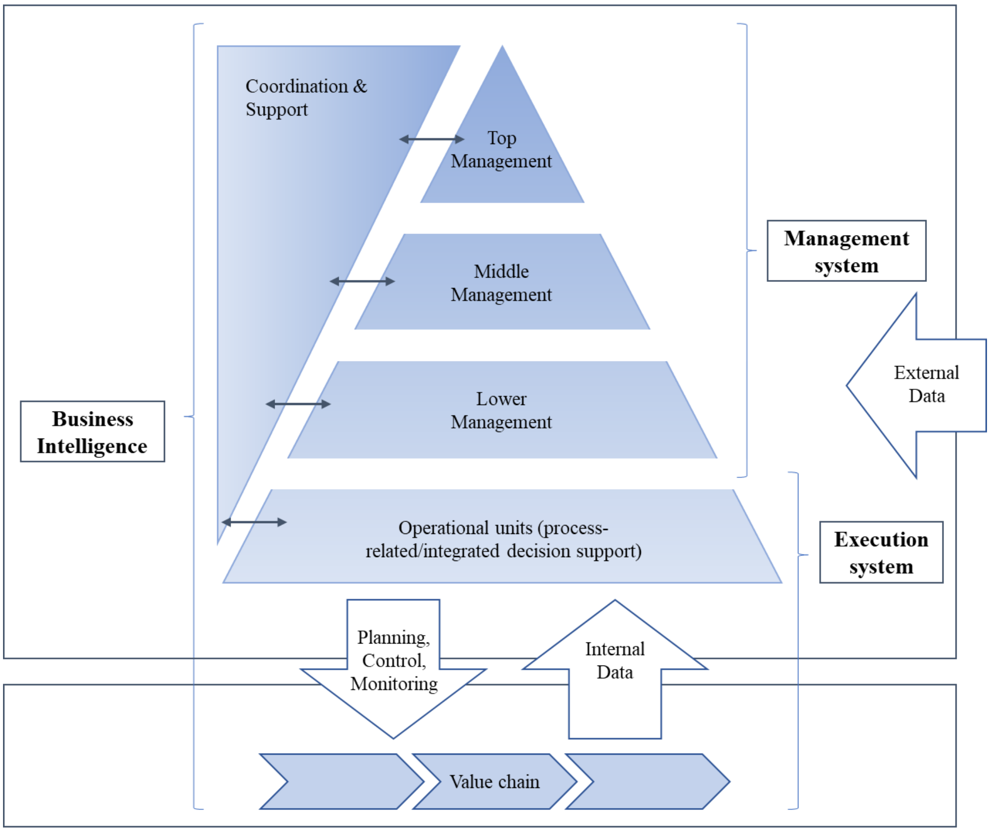
Adapted from Rajnoha, Kádárová, Sujová & Kádár (2014).

In addition to this integration, technological innovations are enabling new trends that favor ERP and BI, including cloud computing and digital transformation. Cloud ERP belongs to the Software as a Service (SaaS) category, which allows companies to obtain ERP services in a cloud environment and provide users with remote access to the ERP (Caserio, 2019). Even if complete outsourcing of core systems to the cloud is not yet an option for companies, SAP manager Höchbauer notes that they see "a clear tendency to obtain new modules or functions from the cloud, even for SAP systems that are operated on-premises" (Eriksdotter, 2021). The use case in the master thesis is also based on cloud solutions. In the backend, which is not the focus of this thesis but should be mentioned here because more and more companies are switching to cloud solutions, a data warehouse cloud is used for data integration. And in the frontend, all reports are hosted in public cloud solutions. The selection of BI tools will be discussed later in the master thesis.

1.1.3 BI as an integrated approach

As described in the previous chapter, BI as an analytical information system builds on the operational systems in the company and forms the logical complement for these systems. It is therefore justified to view BI as an "integrated company-specific, IT-supported overall approach to operational decision support" (Baars & Kemper, 2021, p. 8) and to understand "intelligence" in this context as information that must be generated, stored, researched, analyzed, interpreted and distributed. Looking at Figure 4, it is clear that a comprehensive BI application system's reach extends across a company's entire management level and reaches employees at all management levels.

Figure 4: Field of application of Business Intelligence



Adapted from Baars & Kemper (2021).

Top management refers to the key executives of an organization, including board members and general managers, who primarily make strategic decisions and set corporate goals. Middle management consists of employees such as department and plant managers who translate top management decisions into concrete programs and plans and are responsible for their fulfillment. The lower manager is the lowest unit and forms the interface with the operational units of the company's value chain. They are responsible for the planning, management and control of executing organizational units. In other words, top management is responsible for strategic activities, middle management for tactical activities, and lower management for operational activities (Raaz, 2010).

Caserio (2019) derives the organizational need for BI as follows:

1. “coercive isomorphism …, related to the need to manage a growing amount of data and information. These needs can be determined by the increasingly stringent and complex management needs,
2. mimetic isomorphism …, related to the need to cope with an increasingly competitive, global, turbulent and disrupting environment where timeliness becomes more and more critical in responding rapidly to market demands,
3. decision-making process, associated with the need to deal with more and more complex processes … due to highly competitive contexts that require the increasing use of advanced information technologies and sophisticated decision-making algorithms” (p. 299/300).

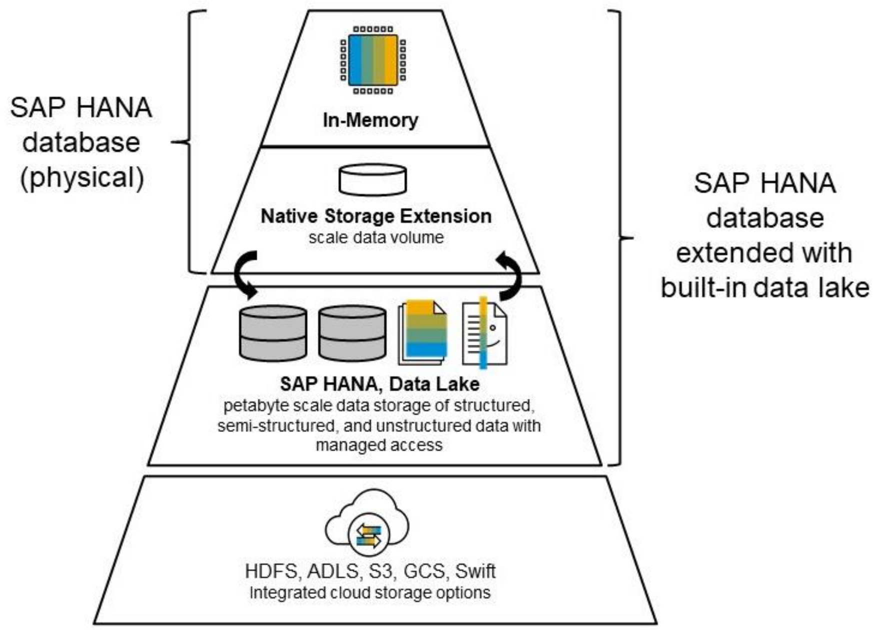
Given the BI application areas and BI needs outlined, it is clear that the concept of a dashboard to be developed and its prototypical implementation spans the entire vertical axis of an enterprise and can support decision-makers at all levels and serve as the basis for strategic business decisions to increase productivity, revenue and growth.

1.1.4 Data as critical success factor

As also emphasized in the previous chapters, digital transformation has brought major challenges for companies, especially with the rise of the IoT. Already today, gigantic amounts of data are being collected and transmitted. Although many companies are now able to collect large amounts of data and also process it into information, there is often a gap in providing this flood of data with the right and correct basis for evaluation and analysis. Enterprise-wide data quality is now considered a critical success factor for BI and part of the company's value, which must therefore be actively managed (Khan, 2021; Işık, Jones & Sidorova, 2013). Rockart (1979) defined the critical success factor as follows: “Critical success factors thus are, for any business, the limited number of areas in which results, if they are satisfactory, will ensure successful competitive performance for the organization. They are the few key areas where "things must go right" for the business to flourish. If results in these areas are inadequate, the organization's efforts for the period will be less than desired. As a result, the critical success factors are areas of activity that should receive constant and careful attention from management” (p. 85). In other words, any business analysis and thus BI efforts depend on high-quality data. If this is not ensured, the benefit of understanding the business, its performance and context cannot be realized and therefore, decision-making cannot be improved (Sauter, 2011). Therefore, it is necessary to define data and information before talking about BI-related systems and activities and BI strategy for system design in the following chapters and even talk about how to project the correct information on the screen to help management make the right decisions.

A modern data architecture, as shown in Figure 5, helps to understand how data quality goals can be achieved. SAP, for example, builds the data layers in its HANA Cloud in a pyramid shape. The lowest level contains the raw data, the so-called cold storage. These have a high volume but do not need to be accessed regularly and can be stored cost-effectively at this level. Data that has a higher value and is also accessed most frequently is the so-called warm data. With the help of the SAP HANA Native Storage Extension, SAP makes it possible to store this warm data and manage cold data. The highest priority is given to the so-called hot data. This data is managed at the top level of the pyramid and is used to store critical business data for real-time processing and real-time analysis (Khan, 2021; Kramer, 2017).

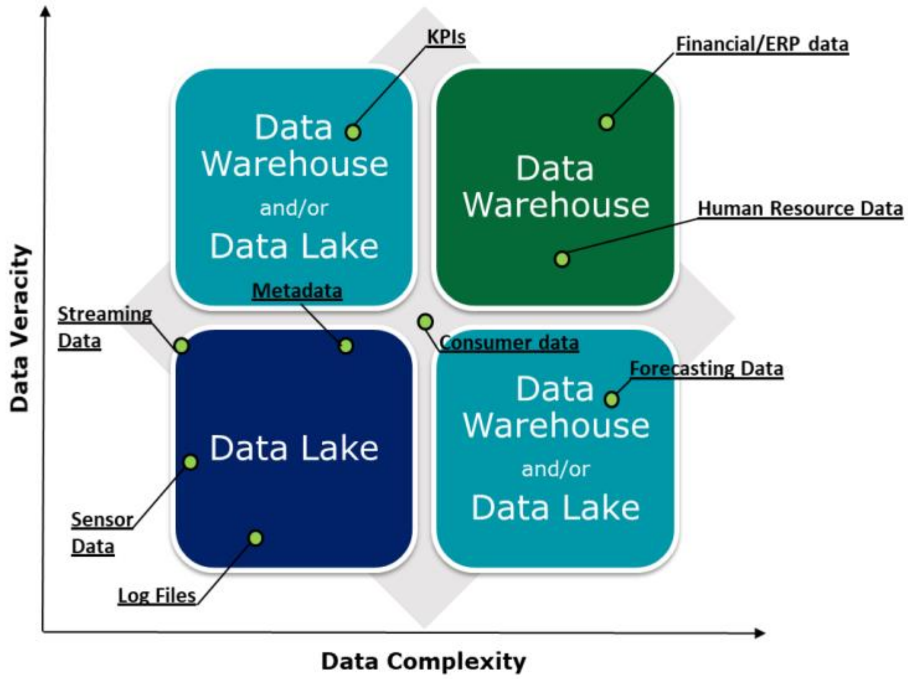
Figure 5: Data Pyramid with SAP HANA Cloud



Source: Klatt (2022).

An important level of the pyramid is the Data Lake. The Data Lake, which emerged with the modern BI environment and is described in more detail in the following chapters, collects raw data from the source systems and is thus available for discovery or analysis at any time. The data lake's types of data ingest and storing are shown in Figure 6. As the figure shows, almost all data types can be stored in a data lake. Decision-relevant data can thus be made available in real-time, and the layers allow data to be moved quickly as needed (Khan, 2021).

Figure 6: Data storage types



Source: Deloitte (2018).

The characteristics of these data themselves can help in deciding whether to include them in the solution design. The characteristics of the data are listed as follows (Sauter, 2011, p. 73):

- Timeliness
- Sufficient
- Level of detail or aggregation
- Understandability
- Freedom from bias
- Decision relevance
- Comparability
- Reliability
- Redundancy
- Cost efficiency
- Quantifiability
- Appropriateness of format

At this point, it is essential to note that there are no universal values. The appropriateness of these characteristics should be defined individually concerning the decision context, the decision-maker, and the decision environment under consideration (Sauter, 2011). Determining data quality spans the entire enterprise data production process. It is not part of this master's thesis, but data quality is a success factor in BI while enabling valid data to be displayed in dashboards.

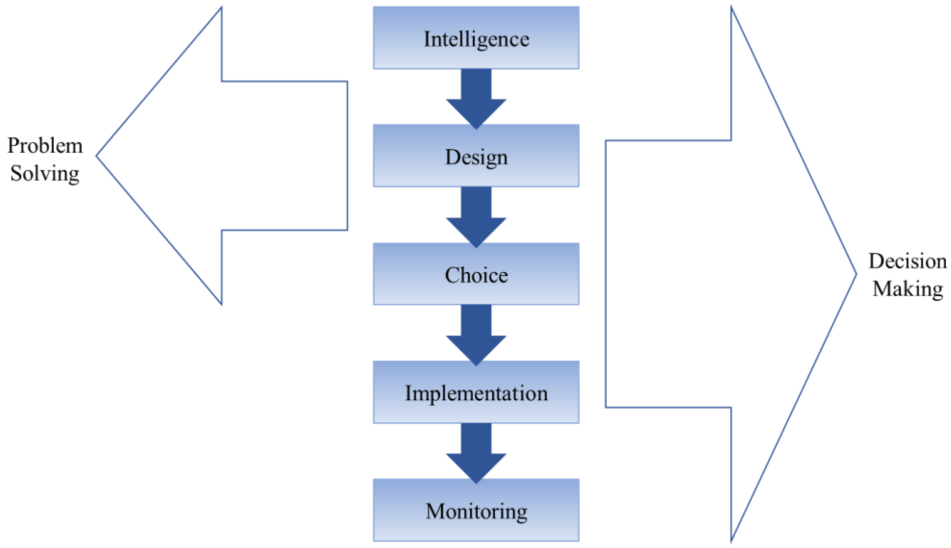
1.1.5 BI-related systems and activities

Chapter 1.1.2 introduced the interaction of BI with other information systems, particularly ERP, and this chapter takes a closer look at the aspect of the BI user to other information activities within an organization, focusing on decision support.

1.1.5.1 BI and decision support

The quality of data processing described in the previous chapter 1.1.4 is closely related to the decision support provided by BI systems. By transforming raw data via data lakes and data warehouses into information and finally into knowledge, BI can support companies in analyzing trends and making forecasts that provide decision-makers with adequate support for their strategic decisions (Caserio, 2019). Although decisions are made daily at all management levels, decision support is not a clearly defined corporate function (Skyrius, 2021). Decisions are made as part of the decision-making process (cf. Figure 7), where potential problems and/or opportunities are first identified and defined in the intelligence phase. Subsequently, alternative solutions to the problem are developed in the design phase, and a course of action is chosen in the selection phase. Finally, in the implementation phase, the solution is put into action, and in the monitoring phase, the implementation of the solution is evaluated (Tripathi, 2011).

Figure 7: Decision-Making and Problem-Solving Process



Source: Tripathi (2011).

Modern decision-making is highly complex. Decisions at the operational level, or lower level of management, are made to support day-to-day operations and fulfill the operational level's strategies and objectives. The strategies at the operational level are the basis for the middle management level. Decisions are made at the middle level to predict future resource forecasts. The strategies at the middle level of management are then the input to the top level of management. At the top management level, strategic decisions are made to achieve business objectives and to validate and review those decisions (Atwah Al-ma‘aitah, 2013). Such complexity places significant demands on the support environment, including the use of sophisticated and problem-specific analysis and modeling tools. A suitable BI tool helps to monitor, review and interpret the information collected. It should not produce more information but provide structure and clarity to support decision-makers in their actions and decisions with short- and long-term consequences (Skyrius, 2021).

1.1.5.2 BI and business analytics

The debate about whether BI and Business Analytics (hereafter: BA) are separate activities or can be subsumed under the term BIA is still not settled. Some sources view BI as backward-looking and BA as forward-looking, suggesting that these terms should be considered separately. According to this approach, BI focuses on data collection and reporting, while analytics projects the future and designs scenarios. It is quite misleading to claim that both approaches can be separated: “according to this logic, BI does not check against our former projections and beliefs as reference points for evaluating current activities and events, and analytics can forecast without using past data” (Skyrius, 2021, p. 43). Other sources define BI as a whole as a tool and process for transforming data about information into knowledge that supports decision-making (Skyrius, 2021). Here, a distinction is made between traditional and modern BI (compare chapter 1.1.6), and the type of data analysis is determined from descriptive to predictive to prescriptive analysis. Descriptive analytics is the type of analysis that is best understood and most commonly used. This analysis looks at evaluating data from the past and tracks key performance indicators to understand the current state of the business. Predictive analytics attempts to derive statements about the future and analyzes trend data through patterns and detected correlations to create an informed forecast. Prescriptive analytics goes a step further and attempts to generate a recommended course of action on how to deal with similar situations in the future. Added to the three types of data analysis today is discovery or wisdom analysis, another level of analysis designed to help companies identify new markets, products and strategies. Figure 8 shows the characteristics of the four types of analyses (Raghupathi & Raghupathi, 2021). Back to the debate itself, Tim Biskuip provides a coherent and well-rounded explanation of this issue: “Analysis without intelligence can’t be done ... that’s guessing and intuition (which still rely heavily on informal intelligence). An analysis that isn’t intelligent is dumb. Capturing intelligence without doing analysis is a waste of time, and intelligence that isn’t based on analysis of intelligence isn’t intelligent.” (Heinze, 2016).

Figure 8: Types of Analytics

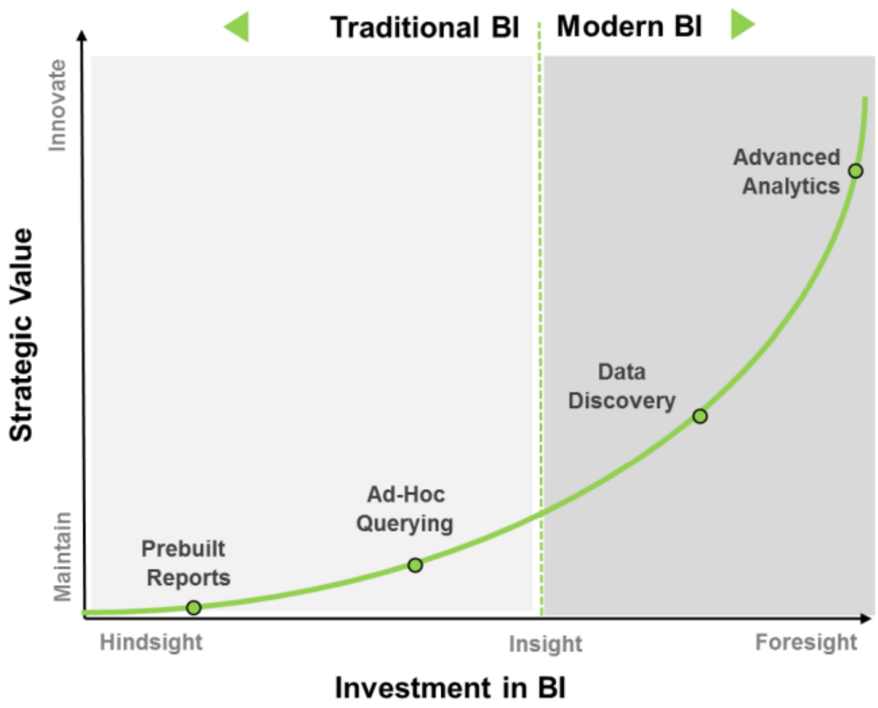
Source: Raghupathi & Raghupathi (2021).

1.1.6 BI strategy for system design

Over the past two decades, traditional BI platforms have focused heavily on providing comprehensive historical reports and user-friendly ad hoc analysis tools. The reason for this lies primarily in the underlying data architecture, which includes a central data storage solution in the form of an enterprise data warehouse (hereafter: EDW). EDWs are at the heart of traditional data platforms and often connect an extensive network of source systems to a central data store. In this process, sources are loaded into the EDW through the ETL process, and the data is then “standardized, cleansed, and transformed in the EDW” (Deloitte, 2018, p. 1) before being made available for analysis purposes. While traditional BI provides a foundation for historical reporting capabilities and maps these types of dashboards and ad hoc reports, this evolved solution presents its own challenges (Deloitte, 2018; Kabakchieva, Stefanova & Yordanova, 2013).

Today's BI users demand easy and immediate access to the data sets they need to make quick management decisions. They are already dissatisfied with traditional BI solutions and want to create their own dashboards using self-service capabilities to link and analyze based on their own knowledge. In addition, there is a need for predictive analytics. As shown in the previous chapter, historical reporting capabilities only provide insight into the past, while predictive analytics provide insight into the future. Companies want to use predictive models to leverage patterns and forecasts to act in a future-oriented manner and make decisions based on this information. Another challenge, according to experts, is the emergence of "Big Data". The term refers not only to the enormous volumes of data but also to the great variety of data. While traditional BI has primarily focused on structured data, users must also look at and analyze unstructured data. Numerous studies show that unstructured data grows exponentially while structured data grows more linearly. This change in available data adds incredible complexity to data integration, transformation and processing. These challenges are driving the need for BI systems to evolve beyond the scope of traditional BI platforms and create new alternatives for enterprises in data exploration and advanced analytics, as highlighted in Figure 9 (Deloitte, 2018; Kabakchieva, Stefanova & Yordanova, 2013).

Figure 9: Modern BI

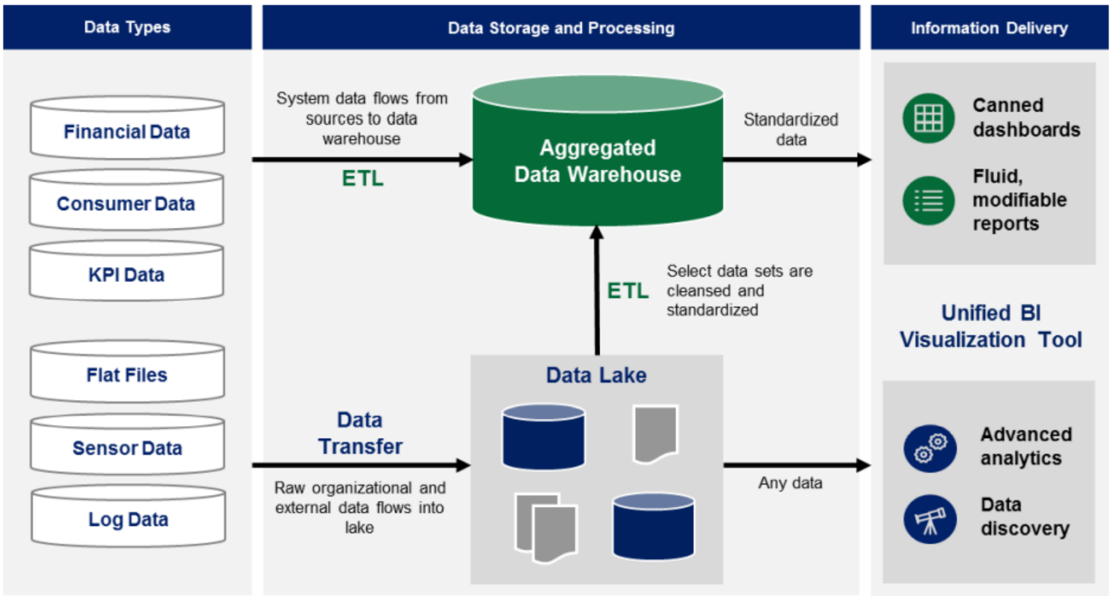


Source: Deloitte (2018).

All the challenges described above are leading to the development of new trends that are already influencing the evolution of BI systems, such as self-service BI, mobile BI, cloud BI, in-memory BI, and software-as-a-service BI, just to name a few. Creating the necessary basis for developments also requires a change in architecture. The concept of data lakes, which was also discussed in the chapter on data as a critical success factor, is being adopted by many companies. A possible system architecture is shown in Figure 10. In this architecture, the data warehouse receives data as usual from various sources that have previously gone through an ETL process. After the data has been cleansed, standardized, and transformed, it is available for analysis by a wide range of users. What is new here is that the data lake now also collects raw data from different systems, which is immediately available for discovery or analysis. This allows enormous amounts of different data to be explored and individualized dashboards to be created for analysis and reporting (Deloitte, 2018; Kabakchieva, Stefanova & Yordanova, 2013).

For this research topic, only the frontend is covered in this thesis. The backend issues, including a trusted database, are not discussed further and are assumed. However, it was important to understand the basic structure of BI to master the use case.

Figure 10: Modern BI architecture



Source: Deloitte (2018).

1.2 Dashboard

Large amounts of data that are constantly being produced in today's world through the use of new media, creating a veritable flood of data, have attracted attention across industries and created enormous expectations for added value (Gandhil & Pruthi, 2020). For business decision-makers, the amount of data generated that needs to be monitored and analyzed is anything but effortless. There is a need to understand big and complex data. In fact, many decision-makers want, most of all is, transparency. They want to quickly and easily identify decision-relevant patterns in business information. Dashboards fulfill exactly this desire (Feldmann & Weller, 2021; Gandhil & Pruthi, 2020). In leading organizations around the world, the term "dashboard" has taken on a whole new meaning as it promotes actionability through improved real-time information systems. In today's parlance, a dashboard is defined as a “rich computer interface with charts, reports, visual indicators, and alert mechanisms that are consolidated into a dynamic and relevant information platform” (Malik, 2005, p. ix). Dashboard displays can change the corporate culture around data usage and are key to the success of any business. They help companies make the most of data and control it in an effective way in turning it into knowledge and making data-driven decisions across the organization (Sharma, 2020; Sosulski, 2019). Their appeal to management is reflected in their prevalence in German-speaking countries. A study from 2019 already showed that 39 percent of the organizations surveyed use dashboards and another 31 percent plan to use them. The 10.4 percent growth in the market for data analytics solutions in the same year also confirms this trend on a global scale. In other words, dashboards are indispensable tools in BI because they help managers understand information and make the right decisions promptly (Feldmann & Weller, 2021; Gandhil & Pruthi, 2020).

1.2.1 Definition and reference frame

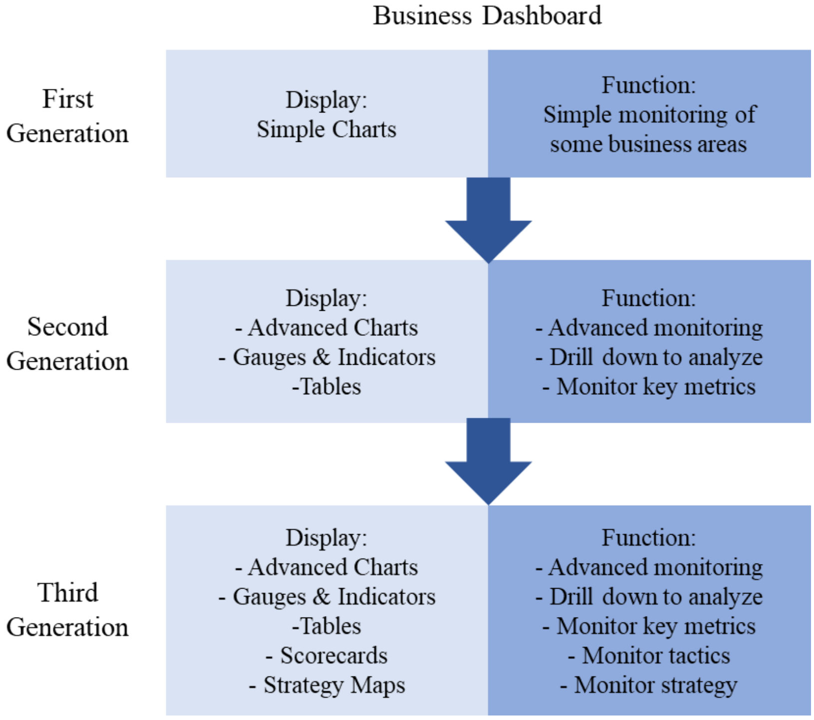
The definition of the term "dashboard" has changed over the years. In 2004, dashboards were still referred to as graphical representations of information and compared to a car's instrument cluster. Since then, management cockpits have become established, which can be interpreted as one of several forms of dashboards but are sometimes understood as a synonym more generally. The name already gives an idea of the form of visualization involved. In particular, speedometer displays analogous to cars or artificially analog display instruments are used here, to display all relevant data in an integrated and perceptible manner at a glance (Jacob, Weiß & Schweig, 2011; Gluchowski, Gabriel & Dittmar, 2008).

Stephen Few gives the definition of a dashboard as "…visual display of the most important information needed to achieve one or more objectives; consolidated and arranged on a single screen so the information can be monitored at a glance" (Few, 2006, p. 34).

Less than a year later, Malik coined the term dashboard with the addition of an "alert mechanism" (see Chapter 1.2).

Eckerson further described a dashboard in 2006 as a "multilayered application built on a business intelligence and data integration infrastructure that enables organizations to measure, monitor, and manage business performance more effectively" (Eckerson, 2006, p. 10). The master's thesis applies this definitional approach for a consistent understanding. For the term "multilayered application" he used the two terms "business information system" and "performance management system" and clarifies that dashboards are much more than just graphical representations of information and that he sees them as an integral part of corporate performance management to achieve strategic goals (Rasmussen, Bansal & Chen, 2009). Corporate performance management, also known as business process management, is a narrower area of BI. After about 20 years of development of BI and related technologies, BI tools have also come of age. They can be used to highlight different facets or levels of detail of a subject. Technologies for business dashboards have significantly evolved. Figure 11 shows the evolution of business dashboards (Jacob, Weiß & Schweig, 2011; Rasmussen, Bansal & Chen, 2009). In this thesis, we will mainly use the term BI and will categorize dashboarding as a part of BI.

Figure 11: Evolution of Business Dashboards



Adapted from Rasmussen, Bansal & Chen (2009).

1.2.2 Types of dashboards

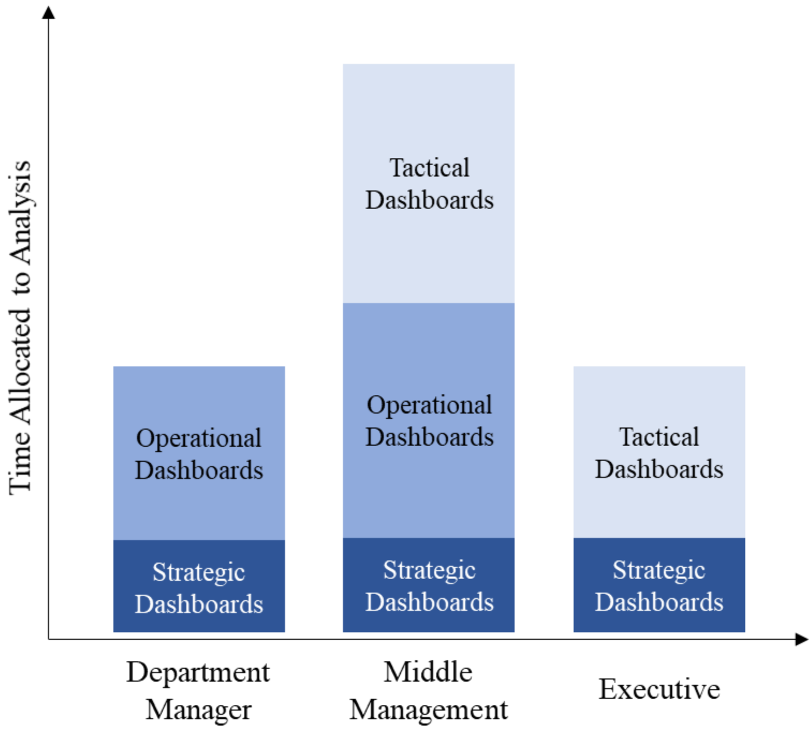
As mentioned several times before, one of the goals of this work is to introduce a cascading dashboard that supports decision-making in all management areas. In the previous chapter, this was clarified given the outlined BI application areas on the vertical axis. Using this it is also possible to subdivide dashboard solutions with all types of content and with almost all types of graphics for all types of users. Hence, the different categories of dashboards are briefly discussed to provide decision-makers with key criteria to help them determine the right type of dashboard for their various purposes.

Logically, dashboards can be divided into the following three main types:

- “Strategic dashboards, which support organizational alignment with strategic goals
- Tactical dashboards, which support the measuring of progress in key projects or initiatives
- Operational dashboards, which support the monitoring of specific business activities” (Rasmussen, Bansal & Chen, 2009, p. 17).

Figure 12 shows managers' use of the three dashboard categories, derived from their level of responsibility and the time they spend analyzing data. Top managers or executives in an organization with the most responsibility spend more time on tactical issues but have less time for detailed analysis. Positions at lower levels in an organization or the operating units tend to have less overall responsibility and also less time available for analysis. In between are middle managers, who are often involved in both tactical and operational issues, which takes up much of their time.

Figure 12: Managers' Use of the Three Dashboard Types



Adapted from Rasmussen, Bansal & Chen (2009).

The purpose of the tactical dashboard is to enable an analysis to monitor the progress and trends for each of its strategic actions. Strategic dashboards enable an organization to monitor progress toward strategic goals. Strategic dashboards are typically highly summarized and graphical, with minimal interaction with the user, provide an overview and consist of the most meaningful data. They are often measured against a predetermined goal, such as a budget or target. On the other hand, operational dashboards are typically used at the department level rather than the management level. Similar to tactical dashboards, they require more detailed information with strong analytical skills to investigate the displayed data for root causes and to take action (Rasmussen, Bansal & Chen, 2009; Ivanov, Larionova, Strugar & Succi, 2019).

1.2.3 Dashboard requirements

The previously presented different categories of dashboards, which are only one of several possibilities, explicitly show that dashboards can be addressed to all areas as well as to the employees of different hierarchical levels in the company and information from dashboards can be output according to different criteria. The morphological box shown in Figure 13 provides an overview of the possible criteria that can be used to customize the classification of dashboards, where several characteristic attributes circumscribe each set of criteria. From the property of the morphological box, any characteristic attribute of these criteria can be combined with any other characteristic attribute of any other set of criteria. Depending on the number and type of combinations, a variety of options can be incorporated into the design of management dashboards through granularity and scope (Jacob, Weiß & Schweig, 2011; Gluchowski, Gabriel & Dittmar, 2008).

Figure 13: Dashboard characteristics differentiated by criteria

Criterion	Attributes				
Range	Strategic	Tactical	Operational		
Purpose	Communication/ Collaboration	Analysis	Monitoring		
Data type	Quantitative	Qualitative			
Application area	Sales	Finance	Marketing	Production	Human Resource
Measured value/ Indicators	General system of indicators	Specific indicators	Balance Scorecard		
Information spectrum	Intercompany	Intracompany	Department-wide	Individual	
Update frequency	Monthly	Daily	Hourly	Real Time	
Interactivity	Rigid	Interactive (Drill Down etc.)			
Presentation technique	Mainly text	Mainly graphic	Integration of text and graphics		

Source: Gluchowski, Gabriel & Dittmar (2008).

Rolf Hichert and Jürgen Faisst, whose recommendations for data visualization and business communication have also been incorporated into the so-called International Business Communication Standards (IBCS), define the characteristics of a dashboard and summarize them under the term "SUCCESS". Each letter of the acronym stands for a separate rule (Baars & Kemper, 2021). In detail, the SUCCESS principles are made up of the following characteristics summarized in Table 2:

Table 2: SUCCESS principles by Hichert and Faisst

1.	Say	Each chart/report/dashboard should convey a clear message, this should also be visually highlighted and expressed in a concise chart title.
2.	Unify	Consistent use of chart elements (symbols, colors, shading, etc.) across all reports/charts.
3.	Condense	High information density
4.	Check	Checking the data and their correct presentation incl. the choice of scales.
5.	Enable	Establish a defined set of rules for visualization/implementation in the organization.
6.	Simplify	Focus on elements that are relevant to the message of the diagram; remove redundancies.
7.	Structure	A clear and uniform order of the presented contents is aimed at (logical arrangement of the elements e.g., in the form of a hierarchy, use of only uniform/comparable elements; no content overlaps between categories; completeness of the presented facts).

Source: Baars & Kemper (2021).

1.2.4 Role of dashboards in a BI solution and their benefits

Some dashboards can be used completely standalone, but typically they are integrated into or used as part of a larger BI solution. In this way, they can be embedded into an enterprise portal that enables the integration of information, people, and processes across organizational boundaries. Even if the use of enterprise portals is not possible because some BI applications do not support them, web-based applications, which are the standard today, can be accessed via hyperlinks, and by embedding them, all users who have a relevant context to the dashboards can access the information. This enables dashboards to be used for strategic alignment (helping managers visualize and track their developed goals and tactics), planning (comparing historical numbers to budgets, forecasts, and targets), reporting (real-time reports to support analytics), and analysis (with analytics modules supporting various functions such as heat maps, drill-downs, statistical analysis, data mining, predictive analytics, etc.) at all levels of the organization (Rasmussen, Bansal & Chen, 2009).

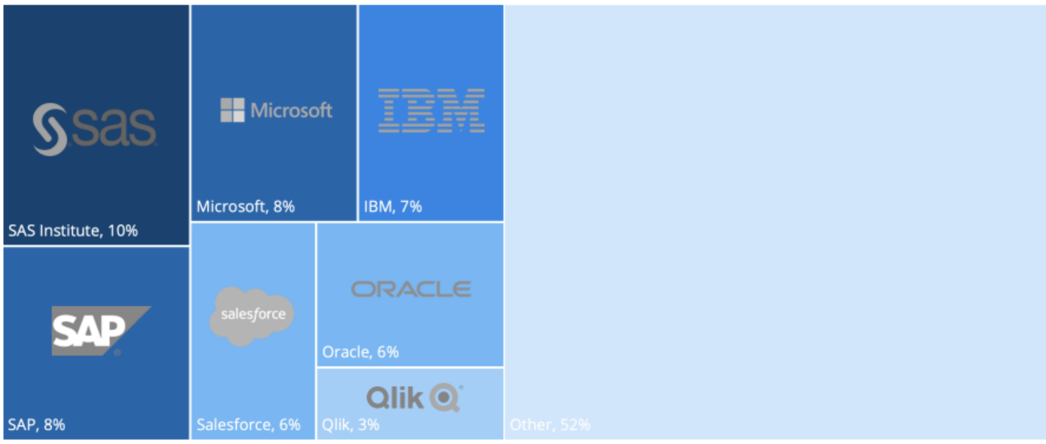
The numerous options and display variants a dashboard offers contribute to its popularity and bring many advantages. One benefit that is certainly significant is improved decision-making and, therefore, improved performance: Better insight into the data allows it to be understood and explored in a variety of ways, thus enabling it to be analyzed to make effective decisions (Gandhil & Pruthi, 2020). Dashboards also make an important contribution to increasing efficiency and employee motivation. Time savings by eliminating the need to create and maintain numerous static reports, more time to analyze data and less time to search for data, low training requirements and ease of learning, tools to share strategies, tactics, and operational data that enable staff to understand goals and make the right decisions are just a few examples (Rasmussen, Bansal & Chen, 2009).

Due to the rapidly growing popularity of dashboards, competition is also increasing among BI solution providers who are trying to establish themselves into the market. They strive to provide solutions for all decision-makers in the company at all levels. And before comparing the BI software of the leading vendors in the empirical part and then selecting the prototype, BI software and its capabilities are presented in the next chapter.

1.2.5 BI software

Appropriately modern analytics and BI software are at the heart of visual exploration and insight gatherings. They enable management to quickly grasp various information at a glance and make directional decisions faster. One definition states that BI software helps users collect, prepare and analyze data to gain actionable insights that can optimize “the health of their businesses” (Zuckerman, 2020). They contain functions for measuring, comparing, and creating user-defined relationships between a variety of data sets (Zuckerman, 2020). BI tools also provide comprehensive data analysis through extensively visualized and intuitive reports. Presenting data in a user-friendly design enables a better understanding of the company's strengths and weaknesses and provides insights into KPIs and other key metrics (Richardson, Schlegel, Sallam, Kronz & Sun, 2021; SelectHub, 2019). The number of providers and the diversity, i.e., the broadly spread market shares in the BI software segment, shown in Figure 14, clearly indicate that BI software is an important tool for securing competitiveness and profitability in the company and is therefore indispensable for most.

Figure 14: Market shares in the segment of Business Intelligence Software



Source: Färber (2021).

2 RESEARCH METHODOLOGY

In the following chapter, the research methodology used to answer the research question of this thesis is presented, as well as the framework and context in which it is used. Using scientific and empirical methods ensures the validity and reliability of the results presented.

2.1 Context

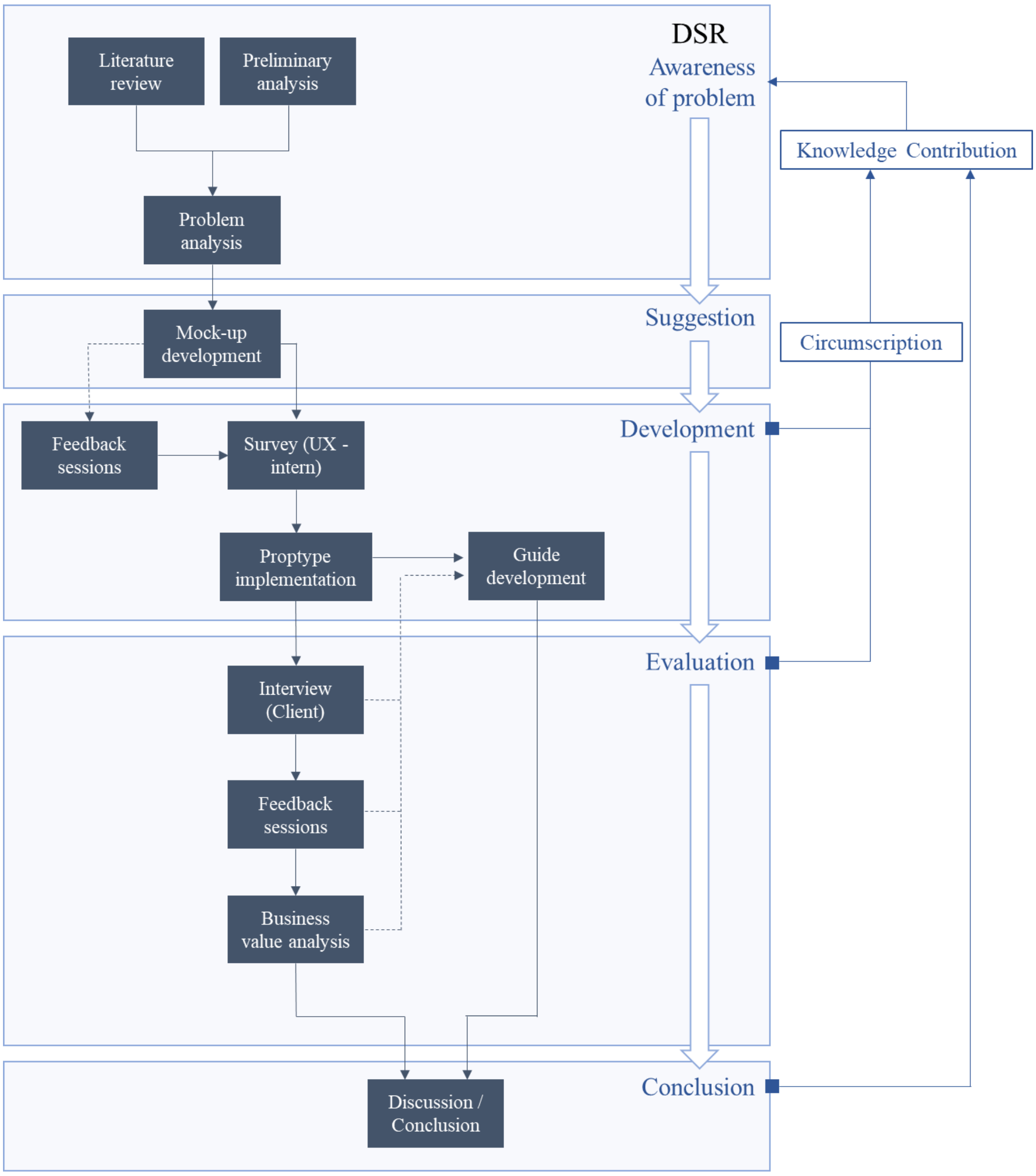
The master thesis is carried out in cooperation with MHP Management- und IT-Beratung GmbH. MPH is a consulting company and subsidiary of Porsche AG, whose consulting focus is on the automotive industry and holistically covers the entire value chain. MHP is one of the leading consulting companies in the areas of mobility and manufacturing, with 3300 employees at 20 locations and sales of 600 million euros in the 2021 financial year (MHP, 2022). The company's other services include the optimization and digitalization of the areas of management consulting, system integration, managed services, and digital services and solutions (MHP, n.d.). The BI department, where this master thesis is written, is part of the Data and Technology (DAT) division. This department is primarily concerned with BI solutions based on SAP technologies, such as SAC or SAP S/4HANA. The solutions offered are intended to show MHP customers what options are available for transforming today's large volumes of data, driven by digital transformation, into a high-quality database, and how the obtained database can be used for transparent reporting via dashboards. For the master's thesis, the company provides requirements and insights into the problem, as well as continuous feedback.

2.2 Framework & Design Science Research

To better structure, the research, Verschuren & Doorewaard (2010) recommend in their handbooks on designing a research project to first outline in broad terms how the research objective will be achieved. They define the research framework as a “schematic and highly visualized representation of the steps that need to be taken to achieve one’s research objective” (p. 19). This type of presentation has proven to be extremely useful in getting a handle on the project. Furthermore, the design science research approach described by Vaishnavi & Kuechler (2004) was chosen as the overarching research methodology for this master's thesis. It is an iterative development process of an artifact, which includes algorithms or human-computer interfaces, among others, that involves two main activities to improve and understand the behavior of aspects of information systems, namely: the creation of new knowledge (rigor) through artifact development and the analysis of the use and performance (relevance) of the artifact through reflection and abstraction (Vaishnavi & Kuechler, 2004). The process is divided into five main steps: Awareness of the Problem, Suggestion, Development, Evaluation, and Conclusion. Each of these steps can be integrated into the framework created to improve understanding of the problem and allow further refinement. Figure 15 shows a visual representation of the framework.

To achieve the research objective, understanding the available literature was first required at the beginning of the DSR approach. More specifically, a literature review of BI and dashboards is described in Chapter 1. To ensure the necessary relevance of the DSR approach, an explanatory case study based on Yin (2018) was conducted as an empirical research method. The case study design is described in detail in Chapter 2.4. To identify the needed design requirements of the artifact, the next step of the DSR process was to assess the initial situation of the case study. A preliminary analysis was conducted with MHP representatives to create a conceptual design, a technology landscape for the project, address the problem, and clarify the scope and limitations of this master's thesis. The combination of these two concepts makes it possible to develop a critical sense of the research project and understand and analyze the problem that has arisen in the project. Based on the preliminary research and consultation with project leaders, the framework was the basis for developing a solution concept that included both the goal for developing the artifact and defined the software used to achieve it. As a design artifact, a mockup dashboard with CSV data was developed based on the selected software solutions to simulate and test the functionalities and integration. In this step, feedback from company representatives was also continuously collected to meet the requirements. Since the DSR approach is an iterative process and this should be reflected in the work accordingly, an internal survey was also created here after the mockup was developed. The mockup was made available to selected MHP employees and a user experience questionnaire (hereafter: UEQ) was created. Given the work's limited nature, the survey results were implemented directly into the prototype, and no further loopback was required. In the development phase of the DSR approach, the prototype was finally implemented with real data based on the feedback and insights from the survey. To gather qualitative findings for the evaluation of the design artifact in addition to the quantitative findings, a semi-structured interview was conducted with potential MHP customers. To avoid exceeding the scope of the thesis, the findings from the interviews were adopted in the conclusion and the prototype's iterative design and evaluation loop was not repeated. In addition to the dashboard, a business value analysis was also conducted to determine if it was worthwhile for organizations to move to a merged dashboard. A guide was also created to help the company deploy the solution in other projects. As a conclusion to the DSR process, the collected results of the case study were used to derive a contribution to practice and theory.

Figure 15: Research Framework



Adapted from Vaishnavi & Kuechler (2004).

2.3 Research Question

The research question addressed in this paper is: How can the use of different BI software be transferred into an integrated concept that supports decision-making at all management levels? As mentioned previously, reporting solutions developed by the departments themselves often lead to heterogeneous BI landscapes or different business logics, which results in high costs for maintenance and/or which led to different results. From this evolves the approach of combining multiple BI tools into an integrated dashboard that can both help preserve preferences in software selection and help all members of an organization move from isolated data use to a fully data-driven culture that provides the foundation for appropriate strategic decision-making.

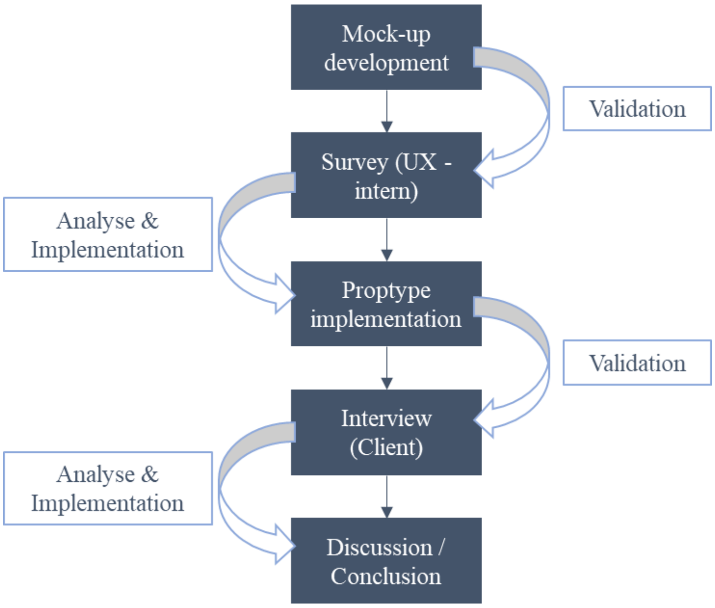
2.4 Case Study Research

The case study, mentioned earlier in the context of the DSR approach, was conducted as an empirical research method to both presents the DSR approach's business requirements and provide the evaluation basis of the design artifact to answer the research question of this thesis. Case study research is considered to be helpful in achieving the purpose and objectives of the thesis because it focuses on an actual phenomenon in a real-world context, i.e., it enables the creation of a theoretical use case and the acquisition of in-depth knowledge about a specific real-world problem (Yin, 2018).

In order to collect data from the case study as a basis for answering the research question, a multi-source data collection approach, according to Yin (2018), was carried out. Chapter 2.5 explains the structure and procedure of the two methods in detail. Both quantitative and qualitative analyses were conducted to increase the validity and reliability of the results. For this purpose, the first version of the design artifact was first tested in the form of a user experience survey. The user experience tests were then validated, and the results were used to implement the next phase of the design artifact, the prototype. After the dashboard prototype was developed, a semi-structured interview was conducted with MHP customers. Subsequently, the interview results were validated and included in the conclusion.

Each version of the prototype is validated. First, the mockup is validated through a survey and then the prototype is validated through an interview. During this process, findings are also shared in a feedback session with the project manager. All collected findings are incorporated step by step into the prototype or presented at the end as a conclusion or outlook, as presented in Figure 16, so that a detailed analysis is provided.

Figure 16: Validation and analysis procedures



Source: Own work.

2.5 Multi-source Data Collection

The following presents the methodological approaches of the individual design and implementation of the two data collection methods. As mentioned earlier, a mixed method of multiple sources was used for the study to increase the validity and reliability of the results. Once the mockup was developed, a user experience survey was conducted. With these results and internal feedback, the prototype was then developed. Finally, a semi-structured interview was conducted with potential customers, focusing on content issues.

2.5.1 Quantitative study

After the initial version of the design artifact was developed, a UEQ was conducted with employees at MHP to measure both the classical usability and user experience aspects of the dashboard. Since the prototype was presented to the customer at the end, it was particularly important first to conduct an internal survey with employees from the front-end area who have many years of experience in various projects and, as experts, know the customer's needs and preferences. 12 MHP employees participated in the survey. Respondents were informed before the survey about the underlying business problem for which the DSR artifact was developed. During a one-week period, the dashboard was released for employees to test the system for usability according to the design artifact's user interface. This allowed participants to complete the evaluation in the form of a questionnaire that was sent by email. The survey can be found in Appendix 2.

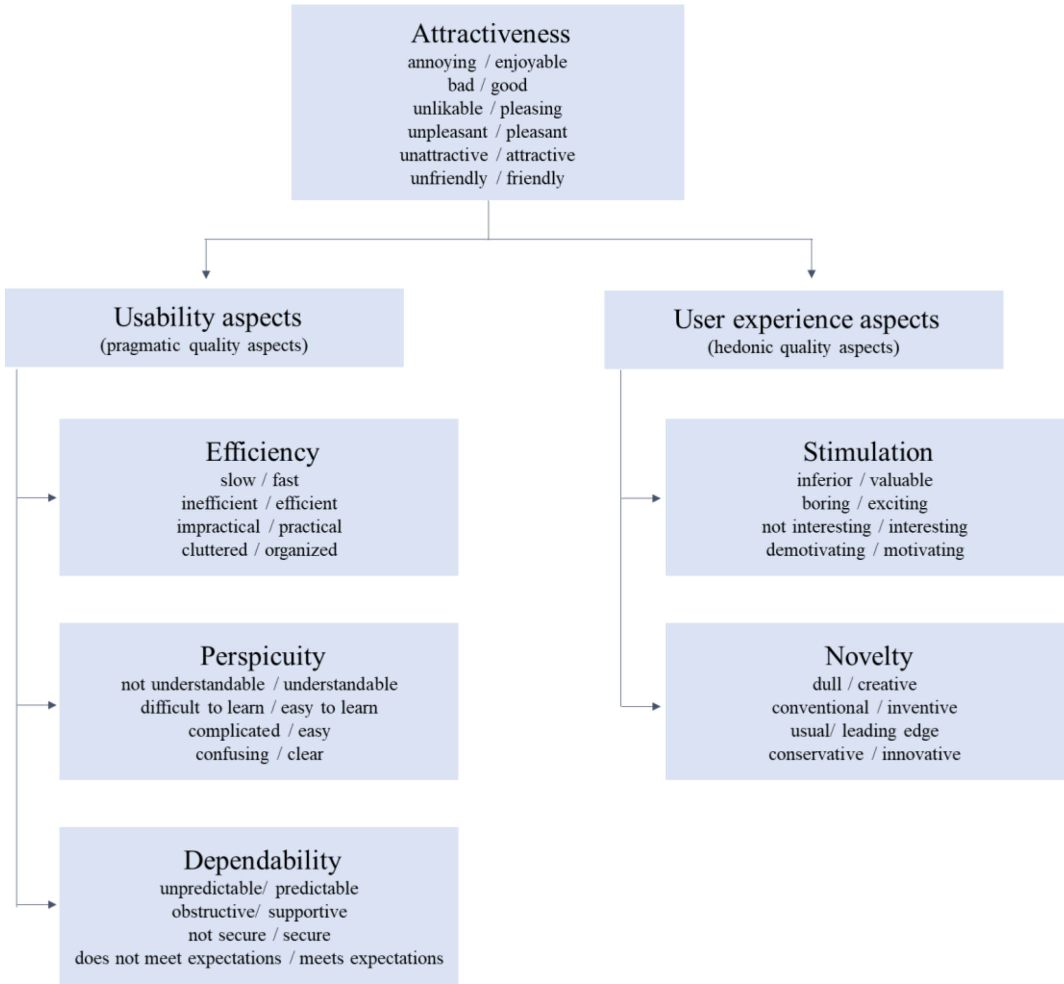
The UEQ developed by Hinderks, Schrepp & Thomaschewski (n.d.) served as the basis for the survey. The questionnaire consists of six scales, including attractiveness, perspicuity, efficiency, dependability, stimulation, and novelty (Schrepp, 2009, p. 2):

1. Attractiveness: Overall impression of the product. Do users like or dislike the product?
2. Perspicuity: Is it easy to get familiar with the product? Is it easy to learn how to use the product?
3. Efficiency: Can users solve their tasks without unnecessary effort?
4. Dependability: Does the user feel in control of the interaction?
5. Stimulation: Is it exciting and motivating to use the product?
6. Novelty: Is the product innovative and creative? Does the product catch the interest of users?

Items are assigned to each scale. Figure 17 shows the adopted scale structure of the UEQ and the items per scale. The items have the form of a “semantic differential”, which means that two terms with opposite meanings represent each item. For each item, a random order of the terms is determined. One half starts with a positive term, the other with a negative term. Four items were selected for each dimension (with the exception of attractiveness, for which six items were selected) to ensure reliability and avoid making the questionnaire unnecessarily long. A seven-point scale was used to reduce central tendency bias in this type of item. However, this was not considered until the results were analyzed since the order of positive and negative terms for an item in the questionnaire is random (Schrepp, 2019).

The collection of quantitative user experience data only provides high-level data on the scales of the UEQ, and the question of which product features need to be improved to enhance the user experience is not directly addressed. In order to obtain the most comprehensive feedback and incorporate employee input into the artifact, additional fields for comments or suggestions are added to the UEQ.

Figure 17: Scale structure of the User Experience Questionnaire (UEQ)



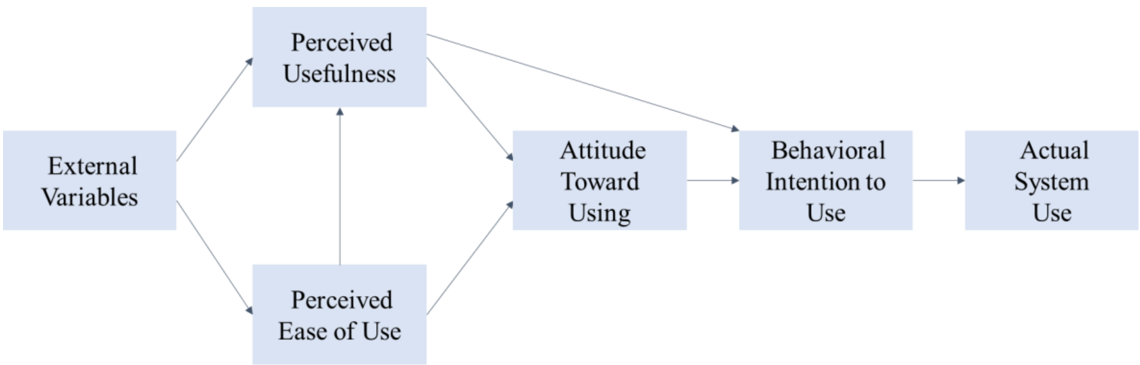
Adapted from Schrepp (2009).

2.5.2 Qualitative study

After the findings of the internal survey had been incorporated step by step into the artifact, semi-structured interviews were conducted with MHP customers. Participants included team and project leaders as well as department heads and executives from the BI and Data Science/Analytics fields. Professionals were recruited through purposive sampling, also known as judgment sampling. In order to assess the feasibility and acceptability of the artifact, it was crucial to assemble a purposive sample and interview experts who resembled a "representative" and were well versed in the content of the research area. The interviewees were informed about the procedure and the course of the interview and their consent for an audio recording was obtained (Saunders, Lewis & Thornhill, 2016). The interview began in each case with the presentation of the artifact. The business problem was discussed, and the solution concept was presented to ensure a seamless interview and avoid possible errors and misunderstandings. Interviews lasted 30 to 45 minutes, took place in German via videoconferencing software at times chosen by the participants, and were subsequently translated from German into English.

The interview questions were developed using the Technology Acceptance Model (hereafter: TAM) initially developed by Davis, Bagozzi & Warshaw (1989), illustrated in Figure 18, and expanded by additional questions. The interview questions in the general form can be found in Appendix 3. If further questions were asked during the interview that was of interest to the answer, these could be read in the respective transcription. The interview was divided into four parts. The first part refers to general questions. The second part refers to questions about the use of information. The third part asked questions about perceived usefulness and perceived ease of use, and the last part refers to questions about the acceptance and usefulness of such a new concept. The original TAM states that attitudes toward using a technology depend critically on two variables: Perceived Usefulness and Perceived Ease of Use. Perceived usefulness is the degree to which a person believes that using a particular technology will improve his or her job performance. Perceived ease of use, in turn, measures the extent to which a person believes that using a particular system requires no effort (Davis, 1989).

Figure 18: Technology Acceptance Model (TAM)



Source: Davis, Bagozzi & Warshaw (1989).

The TAM was chosen because it focuses on the intended use of an information system and is of primary importance to computer acceptance behavior. In the interview, it was also possible to ask more complex and open-ended questions, which allowed deeper insights that allowed contextualizing the previous results of the survey (Saunders, Lewis & Thornhill, 2016). A total of 4 interviews were reviewed and selected for evaluation. Table 3 summarizes the main characteristics of each observation unit in the sample.

Table 3: Sample Units Overview

Interviewees	Company Name	Position within the Company	Interview Type	Duration
User A	Claas KGaA mbH	Head of Data Analytics	Semi-structured	36 minutes
User B	Fischerwerke GmbH & Co. KG	Application Engineer	Semi-structured	34 minutes
User C	Claas KGaA mbH	CRM System Reporting	Semi-structured	45 minutes
User D	Porsche AG	Quality Controlling	Semi-structured	43 minutes

Source: Own work.

Since external respondents participated in the interviews, there was no direct reference to the master's thesis, and a possible bias's influence was reduced to a minimum. In addition, care was taken to ensure that the interviewees were people who are involved with this solution and for whom this technology is primarily a consideration, as it became apparent during the critical literature review that the topic is very current and there is little literature on its practical relevance.

2.6 Data Analysis Methods

Two analyses were conducted as part of the master's thesis. First, a survey and then semi-structured interviews.

The first part of the survey was analyzed at the level of individual questions, which were constructed as items represented by two terms with opposite meanings, to draw quantitative conclusions from the observations. In this case, a seven-point Likert scale was used. Since the items were scaled from -3 to +3, it can be assumed that the data collected represented interval data. Based on the interval data, descriptive statistics were performed for the analysis (Saunders, Lewis & Thornhill, 2016). In order to detect more or less random or non-serious responses common in surveys, a simple rule was used to detect suspicious data at the beginning of the analysis and consider it in the interpretation. Here, the extent to which the best and worst ratings of an item on a scale deviate from each other was checked at the beginning. A significant difference (>3) is considered an indicator of a problematic data pattern. To distinguish such situations from random response errors or a misunderstanding of an item, a response was considered unsuitable if this was the case for 2 or 3 scales. The second part of the survey consisted of additional fields for comments or suggestions per scale in order to incorporate as much employee input as possible into the artifact. Here, following Saunders, Lewis & Thornhill (2016), a thematic analysis was conducted, an approach to identify, analyze, and represent patterns (themes) within data. The focus was on identifying the underlying meaning and making an overall assessment of the message.

In analyzing the qualitative data from the semi-structured interviews, thematic analysis was also conducted following Saunders, Lewis & Thornhill (2016). This involved looking for patterns (themes) in the data in order to draw conclusions and verify them. The use of the TAM to develop the questions and the division of some questions into themes meant that there was already a thematic context, which simplified the analysis. In addition, user experience issues previously addressed in the survey were revisited in the interviews to contextualize the quantitative data from the survey. The findings from the quantitative and qualitative analysis of the data collected form the basis for deriving the contribution to practice and theory.

3 CASE STUDY DESCRIPTION

The structure of the research framework previously shown in Figure 15 is used as the basis for the use case. For the development of the DSR artifact, the business requirements are needed in addition to the theoretical knowledge base to define the research design requirements. The following chapter first introduces the use case and then examines the problem statement to highlight the existing business requirements and the relevance of the DSR approach. Based on the current business requirements and theoretical knowledge base, a mockup, the first draft of the solution concept, is developed, which is the basis for developing the DSR artifact. The subsequent user experience survey of the company's employees successfully identifies the customer's requirements and ensures that a prototype is implemented as realistically as possible. The next step is implementing the solution concept to develop the artifact successfully. The decisions made in this context are justified to create transparency and traceability, and the findings from the subsequent expert interviews with customers are used to enable a holistic implementation of the artifact. After developing the artifact, the final step is to create a business value analysis and a guide for implementing future projects.

3.1 Case Study Introduction and Problem Investigation

As a Porsche subsidiary focusing on the automotive industry, MHP is one of the leading consulting companies worldwide in this field. They are leading business and technology partners, strategically and operationally supporting companies in projects and try to respond to customers' needs and provide them with comprehensive support in many service areas to give them the necessary security for their core business. The use case of this master thesis has arisen from a project with Porsche AG. The following insights were provided by the internal supervisor who described the situation as follows. The German car manufacturer is constantly looking for improvements, regularly putting structures to the test and optimizing them. The company also wants to gain more transparency and an edge over the competition in the BI area and has been trying to develop a holistic BI solution since the beginning of the year. To be able to provide real-time data and precise forecasts, they wanted to standardize the entire BI software and rely on one provider, namely SAP. Thus, they commissioned MHP to convert all BI solutions not running on SAC to SAC. Instead of moving all the dashboards to one software provider, the idea was to develop a concept combining different software in one dashboard. This should, on the one hand, enable departments and, in particular, middle and lower management to continue their analyses using the preferred tools and, on the other hand, help the company to build a unified landscape that maximizes their decision-making and thus their competitive advantage. The fact that the case study is based on a real company ensures that this case's research purpose and research question can also be seamlessly applied to other companies. In this context, the methodology and theoretical concepts used for developing the DSR artifact are applied as a basis for the project with Porsche AG. They are also proposed as a real solution design. The created initial situation is thus a solution concept of the project and could also be used for further projects with other customers.

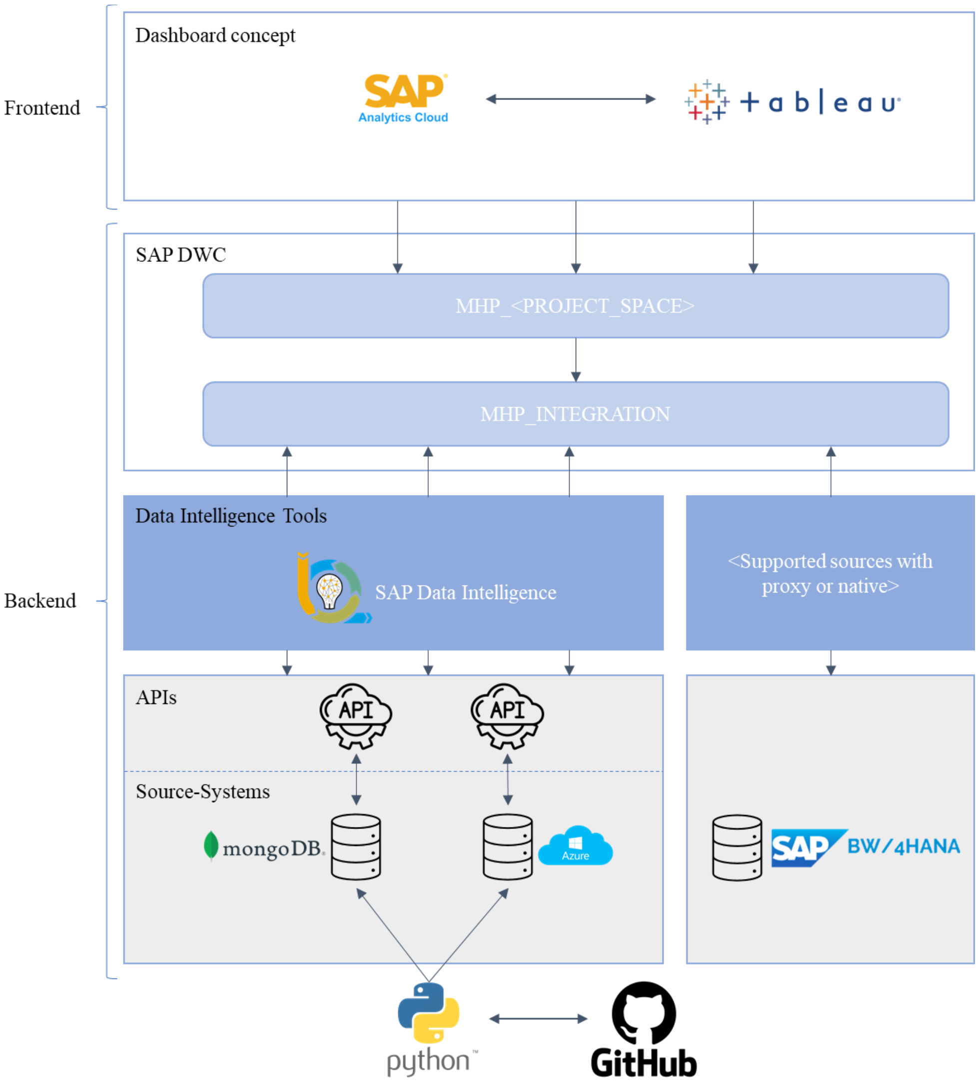
3.2 Solution Conceptualization and Design

Based on the evaluation of the initial situation, a solution concept for the development of the prototype is created that is adapted to the existing framework conditions and the defined goal. In the process, a technology landscape of the project to be realized is first designed. This also creates a unified view, addresses the problem and also clarifies the scope and limitations of this master thesis. Subsequently, different BI software providers are compared with each other to determine the most suitable provider for the individual use case and to be able to select the tool to be used.

3.2.1 Technology landscape

In order to implement the solution concept, it is necessary to make changes to the existing system architecture of Porsche AG. This is shown in simplified form in Figure 19. The data is stored in both NoSQL databases (like MongoDB) and SQL databases (like Azure or SAP BW). For the use case, python and GitHub are used to create artificial data and write it to databases. The sources' different (generated) data types and formats are combined in SAP Data Warehouse Cloud (hereafter: DWC) to create a unified fact base for analysis. To gain these insights from large volumes of data, robust and seamless data integration is required, which is generated with data integration tools. APIs are used to interact with these tools. The data managed in the backend can then be displayed as dashboards using front-end tools. In the case study, SAC and Tableau are used as front-end tools. The choice of software is explained in detail in Chapters 3.2.2 and 3.2.3. The interaction between the frontend tools will be generated through URL-Actions. For the first mockup design, the data is not imported into DWC but linked directly as CSV data with the BI software. Only for the prototype the structure in the presented figure is followed. As it is shown, the project consists of backend and frontend activities. For the creation of the master thesis, the delimitation is also adopted on this basis. The MHP staff provides all backend activities for the project. The implementation in the master thesis only concerns the frontend and topics concerning the backend are not explained further.

Figure 19: Technology Landscape Porsche AG



Source: Own work.

3.2.2 Leading BI software comparison

Gartner, a company known for its analysis of developments in the IT industry, provided an overview of current platforms in February 2021 in what it calls the Magic Quadrant for Analytics and Business Intelligence Platforms. Based on 12 critical capability areas (including functional scope), the company categorizes vendors according to their execution capability and vision completeness, as illustrated in the chart in Figure 20.

Figure 20: Magic Quadrant for Analytics and Business Intelligence Platforms

Source: Microsoft (2021a).

According to Gartner, Microsoft and Tableau are the two leading analytics and BI platform providers. Microsoft, which maintains the Power BI business intelligence platform, stands out in particular. Microsoft offers a comprehensive and visionary product range. It has an enormous market reach through Microsoft Office, which differentiates the functions and capabilities of this product from those of other market players. The most important features include full integration with Microsoft Azure, data preparation, visual-based data discovery, interactive dashboards and advanced analytics using artificial intelligence (hereafter: AI), and comprehensive data protection with Microsoft Information Protection. Tableau is also considered one of the leading providers in this area and is characterized above all by its intuitive design and user-friendliness. According to Gartner, Tableau provides "a visual-based exploration experience that enables business users to access, prepare, analyze and present findings in their data" (Richardson, Schlegel, Sallam, Kronz & Sun, 2021, p. 24). In addition, through the integration of Salesforce Einstein Supports, the new Einstein Discovery feature enables the use of predictions and recommendations in Tableau workflows to optimize decision-making. Another BI vendor that is not listed among the leading providers but still plays an important role, especially in the German-speaking region, is SAP. According to Gartner, SAP is considered a visionary in this Magic Quadrant. SAC is fully integrated into the SAP ecosystem and is, therefore, an important decision criterion for most companies that already have SAP business applications. SAC enables collaboration across business units and allows users to create tasks and share feedback. Users can create reports, perform classic and predictive analytics, or build planning applications from a central cloud platform. In addition, different "stories" can be combined in the SAP Digital Boardroom and visualized and operated on multiple interacting monitors (Richardson, Schlegel, Sallam, Kronz & Sun, 2021; Khan, 2021). Since MHP serves a large number of German customers from the automotive industry and most of them already use SAP in their systems, most of them prefer to use SAC and include it strategically in their planning. Therefore, SAC is used as one of two software solutions for this use case. And considering the aspects mentioned above, Tableau and Power BI are now compared in the following based on specific characteristics and applied as the second tool.

3.2.2.1 Data visualization and analytics

In the field of data visualization, Tableau is one of the industry leaders. Tableau has an intelligent interface that allows even non-technical users to create and customize dashboards to meet individual needs. Using drag-and-drop functions, data fields can be drawn into value, axis, filter, legend and formatting sections. Tableau also allows its users to customize dashboards specifically for a device. Tableau delivers interactive visualizations that provide quick insights. It can transform queries into visualizations that help users find answers to questions, discover developments, and identify opportunities. The investment in advanced networked data, clustering, segmentation and more powerful analytics is reflected in improvements in data federation, streamlined interfaces, advanced analytics and advancements in mobile exploration and creation. Microsoft Power BI also offers convenient data visualization and analysis. With its easy-to-use drag-and-drop functionality, data can also be presented in a visually appealing way. It provides a variety of detailed and attractive visualizations for creating reports and dashboards. Precisely because Power BI has its roots in Microsoft Office 365 and is already familiar to most end users, the product is very user-friendly, and the interface integrates easily with other Microsoft products to create complex data analytics (Biswal, 2022; SelectHub, 2019).

3.2.2.2 Data integration

Processing a wide range of data formats is guaranteed with both tools. They have access to simple files, databases, online services and much more. Both tools support the most common source formats such as SQL databases, JSON, or SAP HANA, just to name a few. However, Power BI supports somewhat limited access to other databases and servers compared to Tableau. Both tools are based on in-memory technology and offer the server as a hosted solution. Via the cloud (Microsoft Azure or Tableau Online), users can create dashboards and reports in minutes and generate live connections and real-time dashboards (Biswal, 2022; SelectHub, 2019).

3.2.2.3 Support and community

Support for both software solutions depends on the license purchased. In the free support provided as part of a purchase-free or educational license, the Tableau Knowledgebase offers detailed explanations on a variety of topics. In addition to textual descriptions, video tutorials are usually available that explain the procedure step by step. For Microsoft Power BI, there is a similar platform to Tableau. On the Microsoft Technical Documentation platform, many documents and tutorials on various topics in diverse Microsoft products can be found. In addition to written explanations and video tutorials, step-by-step instructions with screenshots are also available for many problems. Nevertheless, Tableau offers an advantage in terms of community. With several thousand active users, Tableau has a larger online community than Power BI, as Power BI is relatively new to the market. Google Trends for Power BI and Tableau also show that Tableau is more popular and more frequently searched for on the internet (Biswal, 2022; Tableau, 2022a; Microsoft, 2022b).

3.2.2.4 Costs

The costs for professional use of Tableau and Microsoft Power BI vary depending on the company's size. Tableau offers the option to deploy the software with Tableau Server (on-premises or in the public cloud) or Tableau Online (fully hosted by Tableau), each available as a Creator, Explorer or Viewer license. The Tableau Explorer license for the server for one user costs $35 per month and the Tableau Online license costs $42 per month. The cost of the Creator license for one user is up to $70 per month. On the other hand, the license cost for Power BI Pro is $9.99 per month for one user. For smaller companies, Microsoft's software solution is definitely the cheaper one. However, as the number of users increases, the cost of Power BI increases rapidly. The reason for the rise in costs for Microsoft Power BI is the additional cost of nodes in the Power BI Premium model. The price is $4,995 per node per month. The additional node optimizes performance, increases memory and unlocks more features. Multiple nodes are required to get the most out of the performance in many cases. In this way, Tableau could be priced more favorably for the number of users to be carried (SelectHub, 2019; Tableau, 2022b; Microsoft, 2022c).

3.2.3 Selection of software for prototype solution

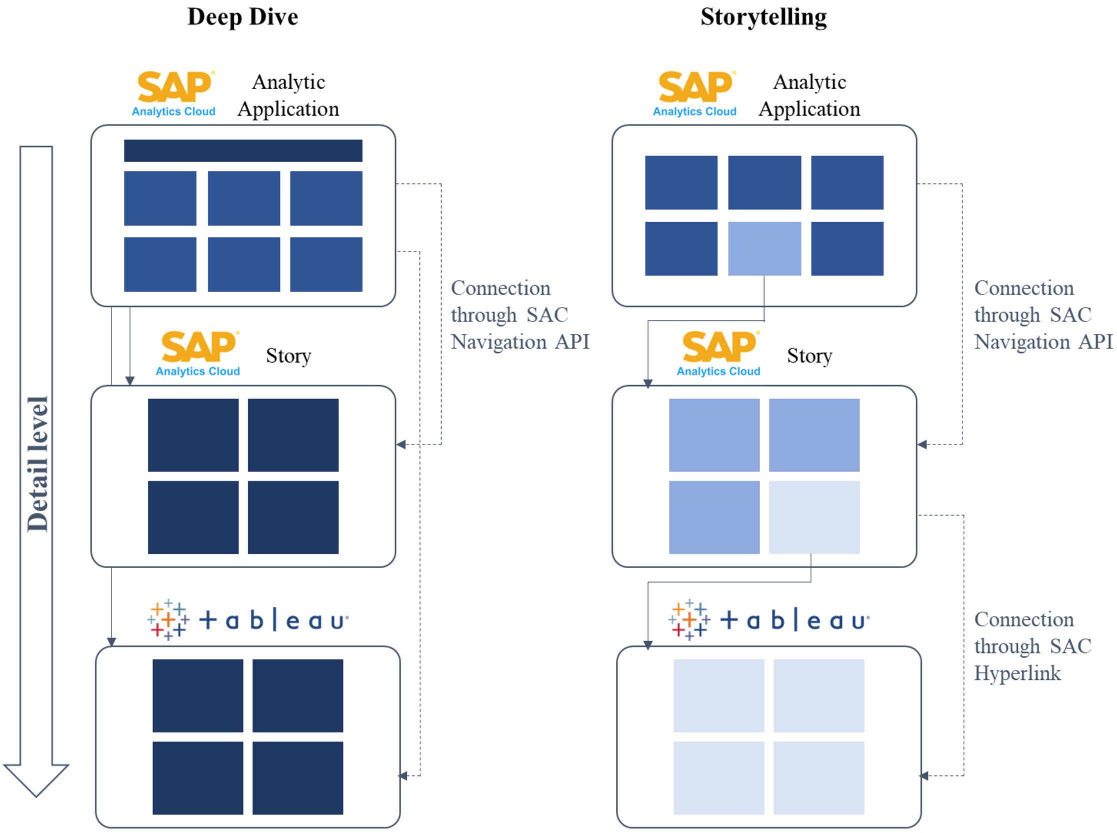
Similar to Gartner's Magic Quadrant, the comparison between the software tools Tableau and Microsoft Power BI shows that both tools meet the requirements to a high degree, scoring similarly on most criteria and excelling in intuitive design and ease of use, with

Microsoft leading in infrastructure support and pricing model and Tableau in ease of use. The decision for software depends on the size and individual requirements of the company. Tableau's expertise in data visualization and analysis in embedded advanced analytics compared to Power BI is clear, Tableau is ahead of many of its competitors in advanced embedded analytics and superior in creating and maintaining real-time dashboards with real-time data integration. Tableau has more effective features for publishing, sharing, and collaboration capabilities for visualizing and analyzing big data. Microsoft Power BI is superior to Tableau in terms of cost. Microsoft offers Power BI at nearly one-third the licensing fee of a typical BI license and also provides one of the most affordable subscription programs on the market. Since Tableau stands out in comparison to Power BI, especially in the area of visualization and analysis, Tableau is used alongside SAC for the use case. The software solution for the use case was developed through the most comprehensive and objective research possible, although it must be emphasized that this work does not claim to have found an optimal standard solution for any use case in the area of merged multiple BI software.

3.3 Solution Concept Integration

With SAC, SAP offers two development environments, namely “Story” and “Analytic Application”, in which companies can create their analyses or visualizations according to the requirements of their business case. Both story and analytic applications offer a wide range of functions that present and understandably visualize the processed data. A story is created in a self-service workflow and is characterized by a clear and straightforward concept that can be created without much effort. The Smart Discovery approach allows the business departments themselves to be involved in the data visualization process. Through AI and machine learning, SAC suggests stories that provide valuable insights with minimal effort. Using a conversational-based approach and a responsive layout, stories are easy to use for both the creator and the user. However, the scope of customization is limited to the options offered in the story environment. On the other hand, analytical applications are suitable for mapping complex requirements and may also have custom logic that cannot be implemented in stories since there is no scripting. Also, the connection between the different BI programs can currently only be made with the analytic application. As described earlier, the interaction between frontend tools is generated by URL actions. With the help of scripting, it is possible to connect SAC applications with other applications, with stories, or even with external software like Tableau in our use case. However, creating such applications also requires greater and deeper knowledge. Nevertheless, from the consumer's perspective, there is no difference between stories and applications in many cases. The consumer is mostly unaware of whether the analytical content is a story or an analytic application. Considering all these aspects and the advantages of Tableau, a structure that connects the software solution, as shown in Figure 21, is most favorable for successful integration that will support decision-making along the vertical axis.

Figure 21: Solution concept integration



Source: Own work.

The solution concept shown in the figure is displayed in two different ways. In the deep dive view, global filters can be used to navigate directly from the overview page to a deeper analysis. The connection is enabled through the SAC Navigation API. In this use case, it is possible to navigate from the overview to another SAP level, in this example, to a story or a new application, namely Tableau. In addition to this option, there is also the possibility of storytelling. The connection among the SAP development environments is again managed through the SAC Navigation API, whereby the connection to Tableau is ensured through hyperlinks. Furthermore, it is also possible to combine the capabilities of Deep Dive and Storytelling. In reality, it is often and mostly the case that you first filter a dashboard by certain dimensions and then move on to storytelling. The idea is to develop a concept that simplifies complicated information so that management can interact with its content and make important decisions faster and more confidently. However, this does not mean that this is the only correct procedure. There are very different ways to design the integration. In this master thesis, however, the method of storytelling is applied.

3.4 Mockup Development

Before the solution concept is designed, a mockup will be developed based on dummy data. For this purpose, datasets are first generated, which are presented in Chapter 3.4.1. In order to ensure a good user experience, a layout is designed in Chapter 3.4.2 that should keep the different user interfaces between SAC and Tableau as small as possible. Based on this, different views of the dashboards are designed, and technical integration is done. To keep the solution design as close to reality as possible, an internal survey is created to test the product for its user experience. This will be validated, and the results of the survey will then be presented in Chapter 3.4.5.

3.4.1 Data preparation

For the collection of the data, fictitious data sets were created with Python. As mentioned several times, the use case was created for the manufacturing operations of Porsche AG. Therefore, production-related data was generated, and it was tried to develop anomalies to enable good storytelling. Here, metadata for laser, powder, and punching machines were created and supplemented with production, material, cost, price, and customer data. It was assumed that the data set was sufficient for a holistic view of the underlying business problem. Therefore, it was decided not to extend the data set with additional data. A detailed overview of the data sets can be found in Appendix 4. In the use case, metal cover and drip pans are produced. Metal covers first pass through the laser cutting machines and then the powder cutting machines and become finished goods, while drip pans only pass through the punching machines and are thus available as a product. The datasets were prepared using Tableau Prep Builder to prepare the data for analysis. Appendix 5 shows a schematic representation of the data preparation process. As part of the data preparation process, a data quality check was performed for column formats, missing values, outliers, data types, or duplicate values. The data was prepared using joins and unions and then output and linked directly to the BI tool to create the mockup.

For the solution concept, the data generated with Python was uploaded to the SAP DWC and prepared there. The dashboard then accesses the DWC and transfers the data accordingly. The preparation in the DWC was created by MHP employees and provided for the master thesis. Therefore, the data preparation will not be discussed further in the following.

3.4.2 Dashboard design

This section presents layouts and color schemes to provide a consistent user experience and uninterrupted flow through the dashboard. This part has been kept short due to the focus of the master thesis and only addresses minimal requirements.

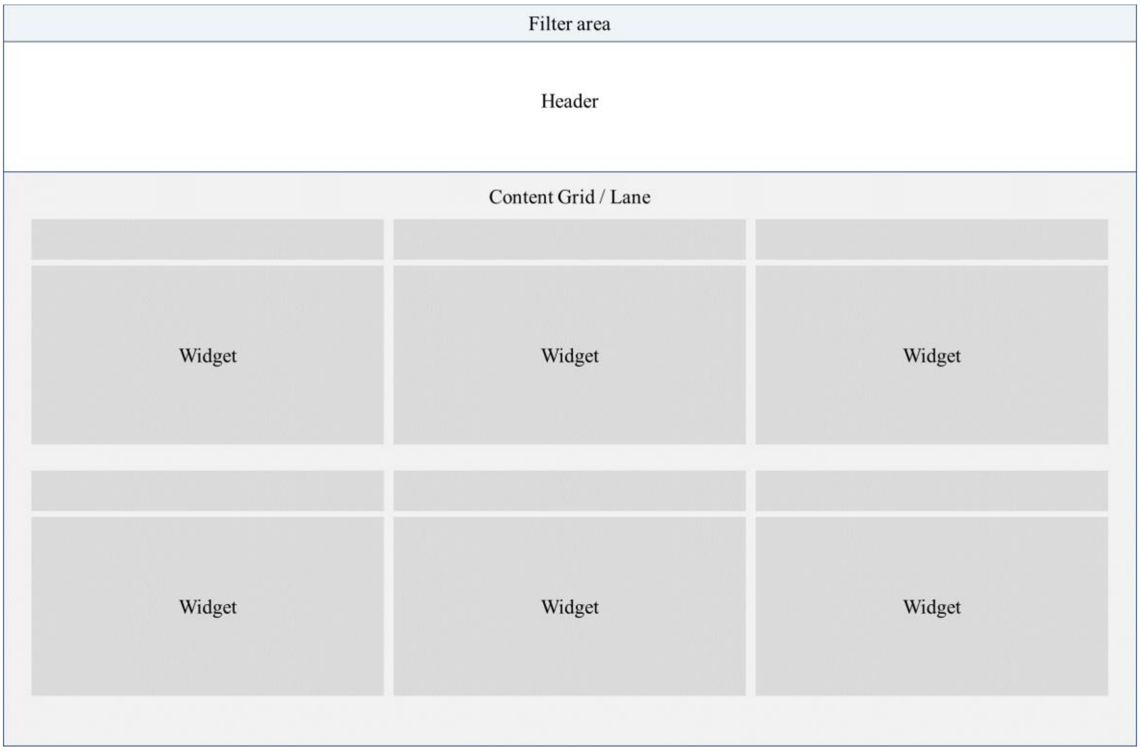
3.4.2.1 Layout

The layout refers to the structure of the dashboard elements. A responsive canvas is used to achieve an optimal layout that adapts to the user's screen. The page design aims to achieve an appropriate information density without cluttering the pages with superfluous content.

The layout of the overview page based on the SAC Analytic Application is shown in Figure 22, and the layout of the deep-dive views of both SAC Story and Tableau is shown in Figure 23. In addition, the most comprehensible forms of visualization appropriate to the characteristics of the data and the intended message are used.

The overview does not display the optional indicators and consists only of the widgets that are located in the content grid or lane. The elements inside the lane are called widgets. Widgets are placed in fixed rows. Some widgets can be made interactive, while others display only static information. The set filter in the header area directly influences the content of the widgets. They are distributed in a uniform style and form three columns and two rows. A total of six widgets are displayed on the overview page.

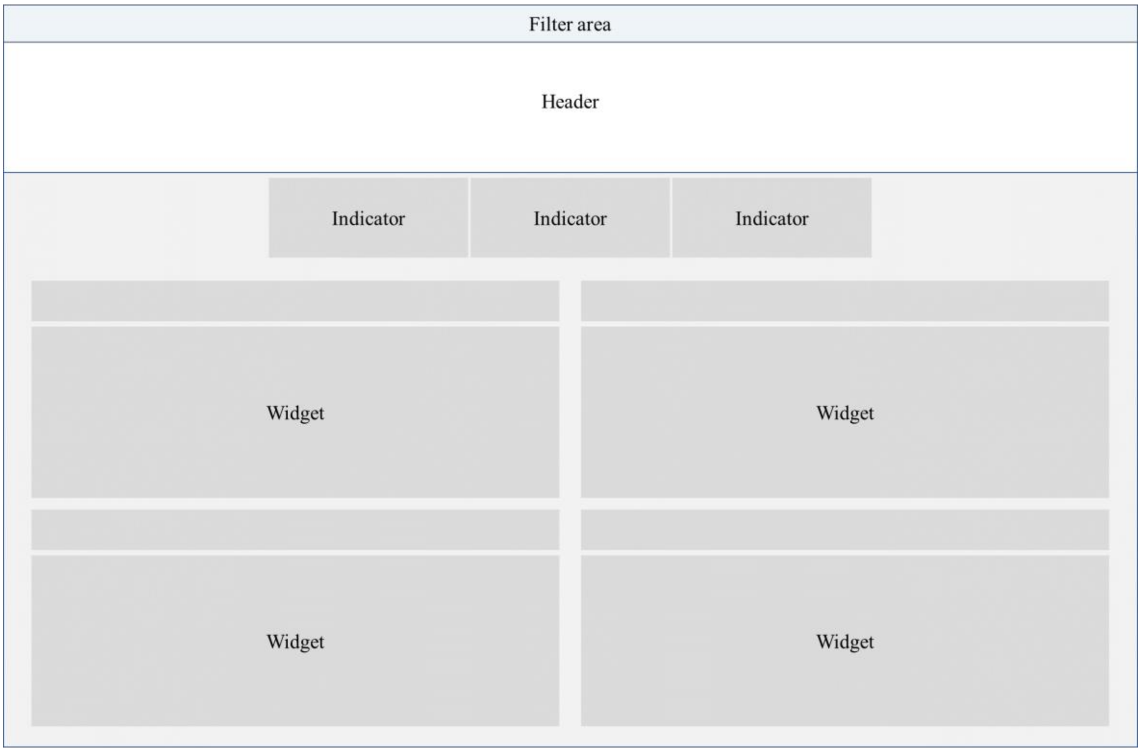
Figure 22: Layout Management View



Source: Own work.

The deep dives additionally include the indicators bar. Widgets reflect detailed information, while indicators focus on a quick and clear information overview without going into detail. The indicators are clear indices from which the user can directly see the context-specific information situation of the current category based on important numbers. The aim is to provide the user with a direct and quick overview of the company's situation within the selected category. They are always located on the top of the selected view. The lane contains all the widgets aligned in a grid layout and enables deep analysis. The lanes set the appropriate distance to other widgets and dashboard elements.

Figure 23: Layout Deep Dive View



Source: Own work.

3.4.2.2 Color scheme

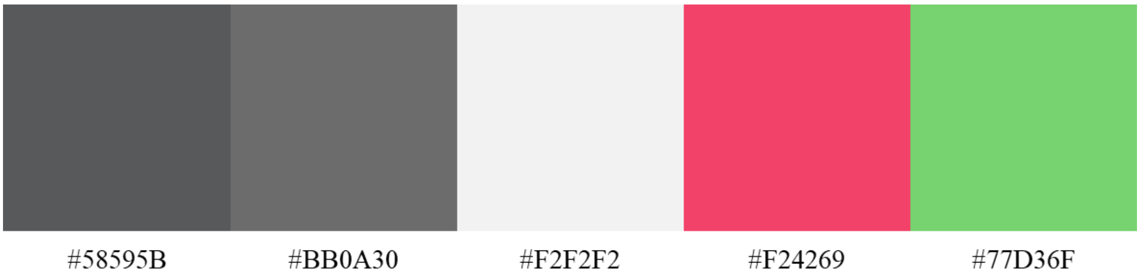
For consistent design and a good user experience, making and recording a suitable color selection is important. Especially when transitioning from one software to the next, it is essential that the same color scheme is used to ensure a consistent integrated solution. For this purpose, a color scheme was created, which consists of several functional color palettes. This was created for a clean and clear design pattern to achieve optimal focus and readability for hierarchy levels, values as well as UI components. Since different BI applications and environments are used, providing the user with a consistent user experience that enables a continuous flow through the views is crucial. Color contrasts were chosen, where each color was carefully designed with syntax meaning and balanced color distribution for dashboard elements to keep the focus on the important aspects. All colors are assigned a unique HEX code, with each palette performing a different task with its color elements. The use of unique HEX codes preserves compatibility for easy addressing of the color scheme and allows straightforward use as a basis for different dashboards.

Figure 24: Layout color scheme

Source: Own work.

The color palettes shown in Figures Figure 24 and Figure 25 consist of ten named color palettes, some of which are derived from the Porsche AG logo and provide the different syntactic meanings and color effects for dark and light ambiance designs to visualize a simple interpretation of different numerical values. This was created for clear, concise designs that follow a minimal, flat style pattern. To highlight the syntax, this aims to provide an uninterrupted focus on important parts of the interface, good readability and quick visual distinction between different syntax elements. While the first palette is used for the user interface, the second is used for the diagrams to be displayed and to visualize negative and positive effects. It aims to highlight the chart elements to ensure undisturbed concentration on essential parts of the data, good readability and quick visual distinction between the different elements.

Figure 25: Content color scheme



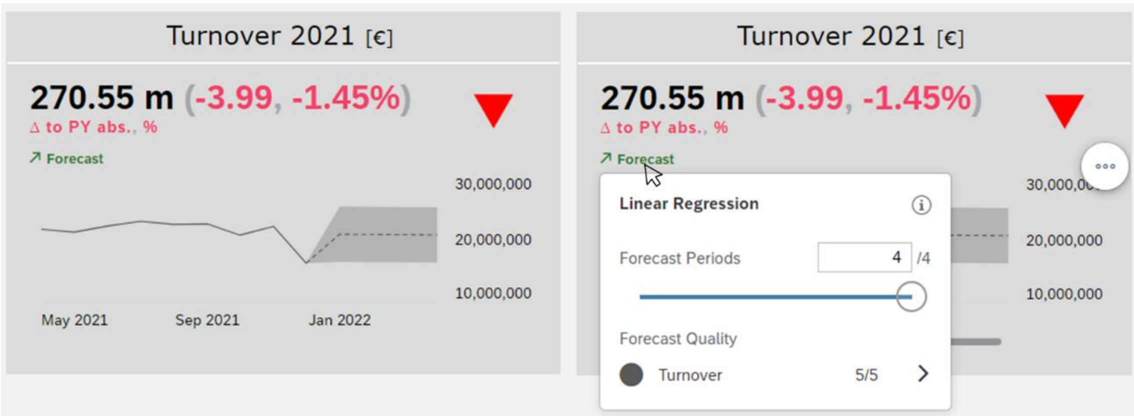
Source: Own work.

3.4.3 Dashboard content

As already described in Chapter 3.3, the dashboard consists of three different layers based on different software tools or development environments. The first page of the dashboard, "Manufacturing -Management View", is used to inform management about the key performance indicators for the company's success. The two following views, "Manufacturing - Deep Dive View", on the other hand, are used for detailed analysis of the production process and are intended to identify problems and their causes and support better decision-making.

The first dashboard page (Appendix 6) contains three widgets in the top row with the key figures: Turnover, Costs and Profit. This provides management with information on whether the company is profitable. The key figures for the current year are shown, along with the absolute and percentage deviation from the previous year, to give an immediate impression of how big the difference is. The deviations were also represented as icons for individuals with a red-green deficit. Dynamic R Visualization was used to create these icons. The codes for the deviations are listed in Appendix 7. In addition, the development over the years is mapped and a forecast is made for the coming year. For the prediction, linear regression is used for historical time series data to forecast future values and derive appropriate measures. The forecast period can also be specified in the analysis itself, as shown in Figure 26.

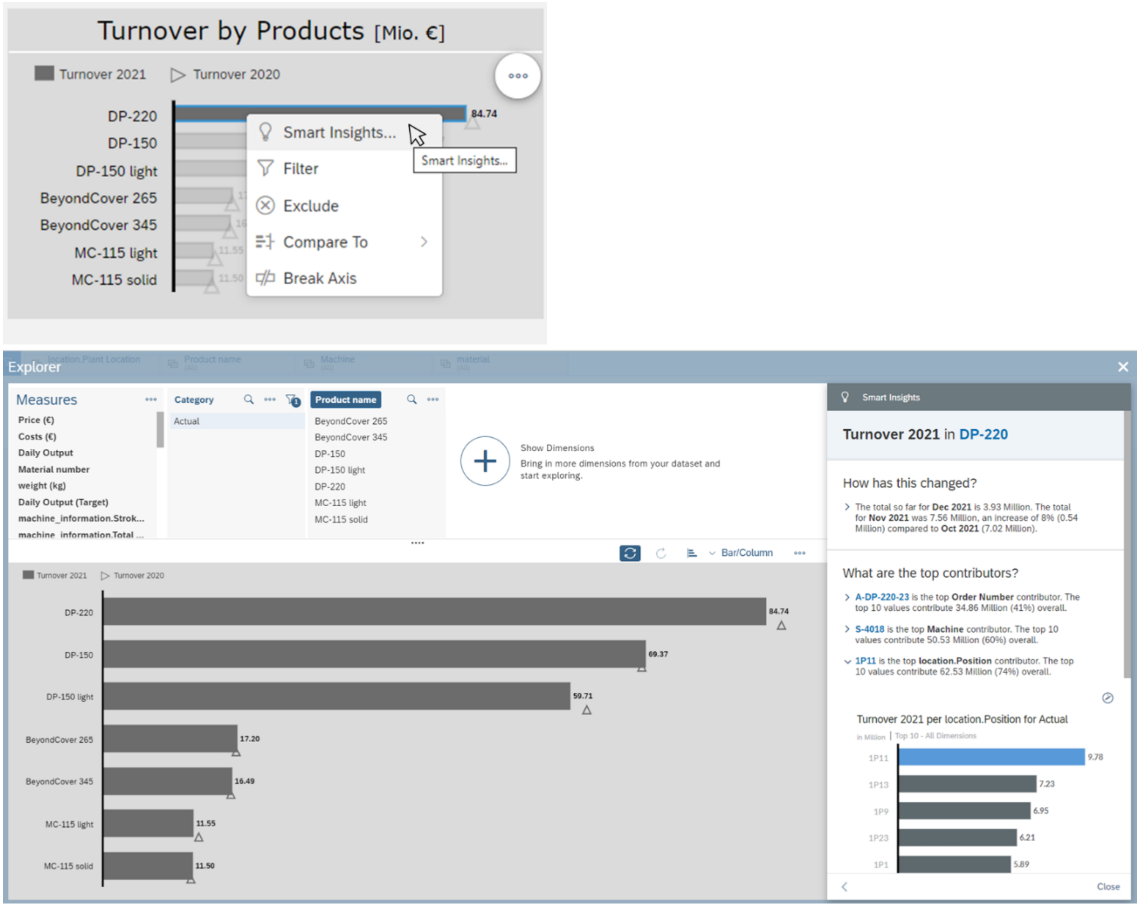
Figure 26: Time series forecasts



Source: Own work.

In the bottom row, the first widget displays the turnover by product. This display is intended to give management an immediate impression of which products are performing well or poorly and what turnover they have generated. It also displays last year's values to understand if these products have performed better or worse in terms of turnover compared to the previous year. Besides, Smart Insight, an augmented analytics feature in SAC, can be used. This feature helps users to identify hidden patterns and complex relationships in their information, even with little or no data science knowledge or experience. The advantage of Smart Insights is that it saves business users much time when they are looking for quick answers to a specific value. The Smart Insight feature is used in most of the charts in the dashboard. Figure 27 shows an example of its use. By clicking the right mouse button, users get to the Explorer view. There, they have the ability to add more metrics or dimensions to their charts without modifying the original graph and are automatically provided with meaningful insights about their data through machine learning that they can use in their analysis.

Figure 27: Smart Insights



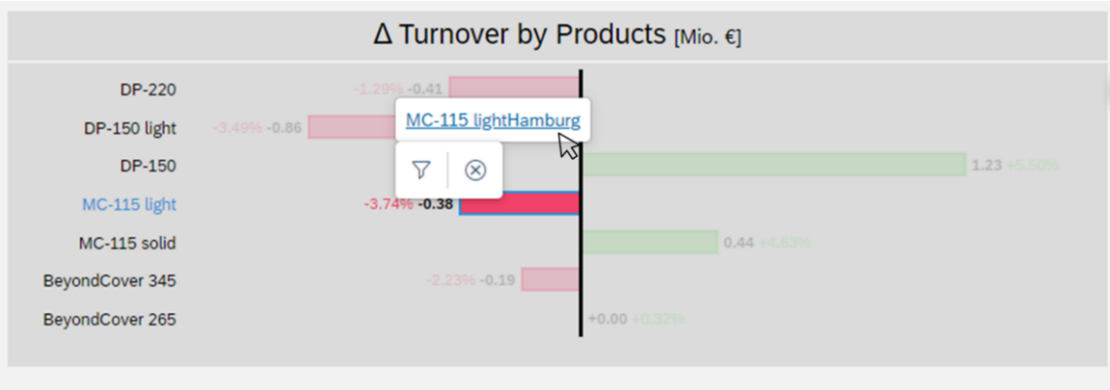
Source: Own work.

The last two widgets on the first page show the distribution in a geo-map to be able to perform visual geo-data analysis, showing the relationship between source and target points and illustrate the top five customers in terms of turnover in bar charts, so that management can immediately visualize how high the turnover is within the selected year.

The filters panel contains the required filter options for the created dashboard. These are called page filters, which interact with all the widgets in the dashboard. This gives the possibility to filter and display the data by plant location, product name, machine and material. In addition, SAC also has so-called widget filters that can be used to filter within a chart. These can also interact with all other widgets in the linked analysis. Clicking on a value jump to the next dashboard page for a detailed analysis and apply the predefined filters. If one wants to analyze the turnover in more detail, for example, one can click on the key figure in the first widget and will be redirected to the next page. For the solution concept, an in-depth analysis was conducted based exclusively on turnover. The dashboard can also be extended with additional pages so that depth views on costs or profit can be created. For the demonstration in the master thesis, this one view is sufficient. The technical implementation of the filter transmission is described in more detail in Chapter 3.4.4.

The second dashboard page (Appendix 8) includes an indicator bar and a total of four widgets. The indicators again show the three key figures, turnover, costs and profit, allowing the user to maintain a direct and quick overview of the company's situation within the selected filters. The listed widgets show the turnover development over the years and the deviations from the previous year by machine type, product and machines. This allows users to see directly which products or machines are responsible for the positive or negative development of the company and in which time periods the cases occurred. After identifying the product or machine that is responsible for the decline in turnover, it is possible to go one level deeper and determine the root cause. To access the page, the user selects the product or machine to be further analyzed and accesses the hyperlink stored for this purpose, as shown in Figure 28.

Figure 28: Access to the last dashboard page



Source: Own work.

Calling the hyperlink will finally take the user to the last page (Appendix 9). This no longer runs in SAC, but in Tableau. The last page is also used for detailed analysis. It also has an indicator bar that shows the three metrics. In addition, the page has two widgets (cf. Figure 29). One of them gives an overview of the previously selected product or machine. All important information such as type of machine, manufacturer, location, and current turnover is displayed in a table. The second widget, which is also in table form, shows the machine's log files and represents the failure's cause. In this way, one can draw conclusions from the decline of a key figure to the causes, starting from the products manufactured to the machines used.

Detailed analysis at three levels thus provides a comprehensive overview of key performance indicators, business strategies and processes in real-time. Building the dashboard in the form of storytelling allows to leverage and communicate the vast amount of insights that the data provides and forms the basis for appropriate strategic decision-making in today's information age. By merging different BI software, this dashboard also allows users to maintain preferences when selecting such software and helps employees to build the most useful reports.

Figure 29: Logfile selected machine

Machine Overview

Machine	Type of Machine	Manufacturer	Type	Country	Plant Location	Building	Position	Turnover 2021	
L-2150	Laserbearbeitungszentrum	TRUMPF	TruLaser 3030	Germany	Hamburg	HH-LCM	1L16	6,81M	1,14%

Laser Cutting Machines (Logfiles)

Machine	Date	Type	Code	Code Description	Daily Output	Daily Output (Target)	Status	
L-2150	16.01.2020	TruLaser 3030	P-156	Low voltage to fiber laser	400	400	Warning	
	17.04.2020	TruLaser 3030	P-156	Low voltage to fiber laser	400	400	Warning	
	24.05.2021	TruLaser 3030	P-156	Low voltage to fiber laser	400	400	Warning	
	23.06.2021	TruLaser 3030	P-156	Low oil pressure	400	400	Warning	
	02.08.2021	TruLaser 3030	P-187	High operating temperature	400	400	Warning	
	25.11.2021	TruLaser 3030	P-187	High operating temperature	400	400	Warning	
	07.12.2021	TruLaser 3030	P-116	Cooling water level too low	390	400	Error	15
			P-156	Low oil pressure	390	400	Warning	

Source: Own work.

3.4.4 Technical integration

As shown in Chapter 3.3, the filter parameters are transferred from the analytic application to the story via the SAC URL API and from the story to Tableau via hyperlinks. This chapter describes the basic operations of such an integration, and a detailed guide for active users can be found in Chapter 3.7.

With the SAC Open Story URL API, stories can be opened directly via URL in a browser and filtered with additional parameters. There are a total of three required parameters that must be defined to apply filters to a story. The first required parameter is the model. This parameter identifies the model to be filtered. The ID can be read from the model information. The next parameter to be defined is the dimension to which the filter is to be applied. Only the technical ID of the dimension will be used. The last parameter is the member, i.e., the filter values for a dimension. This is where one can enter the IDs of the dimension members that one wants to filter. In addition, there are further parameters that can be optionally configured. These can be found online in the SAP documentation. The selected values must be called in the filters (dimension filters or widget filters) to access the filter values. Thereby, the parameter values must be URL-encoded to work properly. To ensure that single and multiple selections are also transferred correctly, the filter values are passed in an if loop in coded form. Appendix 10 shows the transcription of the transmission of the filter parameter for the filter "plant location".

Since the story mode has no scripting function, the filter transfer from a Story to the external software is done via a hyperlink. URL parameters can be used to filter the data that is displayed when the view is opened. To be able to filter for a value in Tableau, the following addition is inserted after the URL: "&Dimension ID= Identifier". To keep the user interface as similar as possible between the different tools, Tableau's navigation pane and toolbar can also be hidden in the embedded view. To hide the navigation pane, ":embed=yes" is inserted after the URL, and to hide the toolbar, ":toolbar=no" is inserted after the URL. The hyperlink for transferring the filter parameters for the "Product" filter is shown in Appendix 11. In this way, the parameter values can also be applied to other target architectures, thus enabling a seamless analysis.

3.4.5 Survey results

After informing employees of the underlying business problem and presenting the mockup, the survey was sent to all participants for further evaluation of the artifact.

Prior to the beginning of the analysis, the responses were reviewed for inconsistencies. A total of three discrepancies were found, by user 3 for perspicuity, by user 11 for novelty, and by user 12 for efficiency. However, since these only occurred on a single scale, they could be interpreted as the result of a random response error or misunderstanding of an item and are not considered problematic or indicate non-serious responses. Therefore, all responses from the data set could be used for the analysis. As already mentioned, the items in the questionnaire were randomized at the beginning. In order to be able to use them for statistical calculations, they have now been transformed. A scale value of -3 to +3 was chosen here. +3 stands for the most positive and -3 for the most negative value.

Table 4 shows the results of the UEQ for the mockup. All in all, the mockup was rated very positively. In addition, no outliers were found in the ratings, and the distribution of the responses to the individual items presented in Appendix 12 shows no polarization of the responses. In particular, attractiveness with a mean of 2.028 and stimulation with a mean of 2.083 are favorable for the artifact and show that users have a good impression of the dashboard, find it exciting and are motivated to use the dashboard:

- "The dashboards are nice to look at and their interactions make you want more." (User 5)
- "Very structured and clear layout design." (User 8)
- "Through various interactions within and across the different diagrams, the end-user is motivated to further interact with the dashboard and get an even better understanding of the data." (User 8)
- "The selection of different visualization options guides the user through the dashboard." (User 9)
- "Dashboard adds value by compactly presenting KPIs and linking multiple BI tools." (User 9)
- "I like the use of signal colors only. They have a meaning. It takes the focus on the important things." (User 10)

In terms of dependability, the mockup scores rather average with a mean value of 1.292. This is aimed at the question of whether users feel in control of the interaction. An important reason for the lower score compared to other scales is that aspects such as predictability and safety were difficult to assess in such a short test period. This was also mentioned by one respondent:

- "I think it's hard to test because it would only show up after GoLive if some real users would access it." (User 5)

The artifact also performs very well on all other scales. Users consider the dashboard easy to understand and user-friendly and the simple design appropriate and sufficient. Furthermore, the feedbacks confirm that the characteristics of a dashboard presented in the theoretical part are reflected here and that the SUCCESS principles presented in chapter 1.2.3 have also been implemented:

- “Understanding and both BI tools well connected.” (User 3)
- “Good overall coloring and readability.” (User 8)
- “The user can quickly find the desired content.” (User 9)
- “It is easy to get familiar with it.” (User 10)
- “Clean interface that is responsive.” (User 11)

From the numerous feedbacks, it is evident that the structure of the mockup is successful and adequately addresses the entire management level. The first level is highly summarized and graphically designed that consists of the most meaningful data and gives the user (top management) an overview. The second level of the dashboard creates an analysis to monitor progress and therefore trends for each of their strategic actions. This level allows middle/lower management to accomplish their work and is consistent with the purpose of the tactical dashboard. The last level provides more detailed information and will enable users (operational units) to investigate the displayed data for causes. Such a structure makes it possible to analyze a problem down to its root cause and act and make decisions accordingly.

- “By jumping across multiple systems, I think the reporting meets the needs of the departments exactly. This should be pursued further.” (User 5)

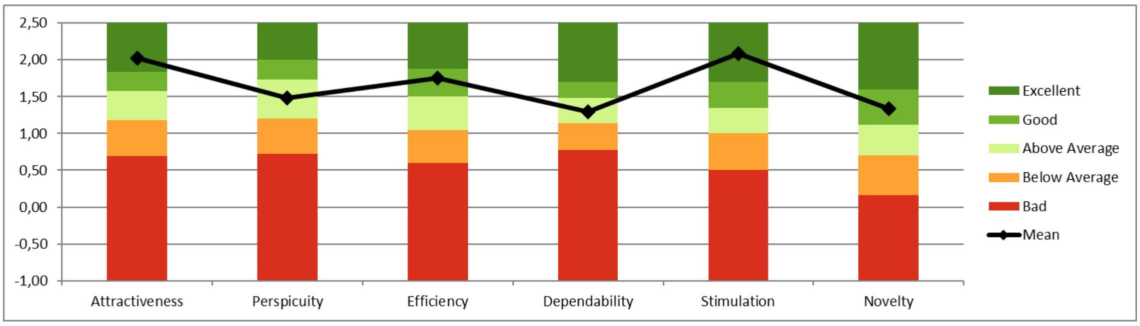
Table 4: UEQ scale means per person and average

	Scale means					
	Attractiveness	Efficiency	Perspicuity	Dependability	Stimulation	Novelty
User 1	1.67	1.50	1.50	1.25	2.00	0.25
User 2	2.67	2.50	0.75	1.50	2.75	2.50
User 3	2.50	1.25	0.75	0.50	3.00	2.50
User 4	1.00	1.00	2.00	0.50	1.00	0.75
User 5	2.00	2.25	2.50	1.75	2.00	1.75
User 6	2.00	2.25	1.75	2.00	2.50	1.75
User 7	1.50	1.00	1.75	1.25	1.25	-1.00
User 8	2.83	2.25	2.00	1.25	2.25	1.75
User 9	2.67	2.75	1.75	1.50	3.00	2.50
User 10	2.17	2.00	1.50	1.50	1.25	1.25
User 11	2.50	2.50	2.50	2.25	3.00	1.50
User 12	0.83	-0.25	-1.00	0.25	1.00	0.50
Average	2.028	1.750	1.479	1.292	2.083	1.333

Source: Own work.

The assessment of whether the user experience of the dashboard is sufficiently high to meet users' general expectations can be answered by comparing the results for the product with the results of a large sample of other commonly used products, i.e., a benchmark data set. The UEQ (Version 10) contains data from 21,175 persons from 468 studies concerning different products (business software, web pages, web shops, social networks). The comparison of the results for the evaluated dashboard with the benchmark data, shown in Figure 30, allows conclusions to be drawn about the relative quality of the artifact compared to other products.

Figure 30: Comparison of the results for the dashboard with the data in the benchmark



Adapted from Hinderks, Schrepp & Thomaschewski (n.d.).

In order to compare the assessment results with the benchmark, the following 5 scales were defined whose benchmark intervals for the UEQ scales are listed in Table 5:

Table 5: Benchmark intervals for the UEQ scales

	Attractiveness	Perspicuity	Efficiency	Dependability	Stimulation	Novelty
Excellent	≥ 1.84	≥ 2.0	≥ 1.88	≥ 1.7	≥ 1.7	≥ 1.6
Good	≥ 1.58 < 1.84	≥ 1.73 < 2.0	≥ 1.5 < 1.88	≥ 1.48 < 1.7	≥ 1.35 < 1.7	≥ 1.12 < 1.6
Above Average	≥ 1.18 < 1.58	≥ 1.2 < 1.73	≥ 1.05 < 1.5	≥ 1.14 < 1.48	≥ 1.0 < 1.35	≥ 0.7 < 1.12
Below Average	≥ 0.69 < 1.18	≥ 0.72 < 1.2	≥ 0.6 < 1.05	≥ 0.78 < 1.14	≥ 0.5 < 1.0	≥ 0.16 < 0.7
Bad	< 0.69	< 0.72	< 0.6	< 0.78	< 0.5	< 0.16

Adapted from Hinderks, Schrepp & Thomaschewski (n.d.).

- Excellent (in the range of the 10% best results)
- Good (10% of results better, 75% of results worse)
- Above Average (25% of results better, 50% of results worse)

- Below Average (50% of results better, 25% of results worse)
- Bad (in the range of the 25% worst results)

However, it should be noted that user expectations have increased over time. Therefore, this comparison should be taken with a grain of salt and the dashboard should at least reach the “above average” category in all scales. The benchmark comparison shows that the dashboard scores above average in all scales. While clarity and reliability are rated “above average”, efficiency and novelty are rated “good”, and attractiveness and stimulation are even rated “excellent”. This also makes it clear that the mockup essentially satisfies the user experience and user interface conditions.

A questionnaire like the UEQ is very efficient, but it also has disadvantages. This form does not support the question of which product features need to be improved to enhance the user experience. Therefore, the second part of the survey included suggestions for improvement in order to be able to derive as concrete action measures as possible and thus also avoid the disadvantage of such a UEQ survey. This is because the input of the employees made it possible to improve the mockup. All feedback from the internal survey is included in Appendix 13. From this, the most important conclusions were drawn and integrated into the dashboard. The adjustments are presented in Chapter 3.5 together with the corresponding justifications.

3.5 Prototype Implementation

In this chapter, the recommendations for action identified in the survey are first incorporated into the solution concept and the final prototype is developed. The prototype is then demonstrated to potential customers in an interview to get their opinion, and finally, the results of the interview will be validated and presented.

3.5.1 Adjustments to mockup

By analyzing the data collected, specific recommendations for action can be derived from the survey, which will be explained in more detail in the following. The main recommendations that emerged from the survey are as follows:

- A landing page to improve the user experience of the dashboard by creating a central navigation point for the user.
- Support by displaying information to help the user understand the dashboard.
- A clearly recognizable navigation that guides the user through the dashboard.
- Increase the information density of diagrams.
- A home button that allows the user to return to the original dashboard.

Home screen

One recommendation was to introduce a home page that would make the dashboard more attractive overall:

- “One landing page with process and business story might make it more attractive.” (User 1)

The introduction of a “Home Screen” (Appendix 14) not only adds value by improving the usability and user experience of the dashboard but also allows navigation to the relevant pages for direct detailed analysis. Although this is not part of this work, it is also possible to use the start page to address compliance issues such as the authorization concept and to define data access rights.

Information display

Other feedback was related to the overall understanding of the dashboard and the nature of the analysis:

- “Filters are not clear, only technical descriptions.” (User 4)
- “Navigation is not directly apparent to the user.” (User 9)
- “Legend for navigation and used colors or objects (Info button).” (User 9)

For an unfamiliar user who does not work with the dashboard on a daily basis, it can be challenging to navigate through the analysis. Therefore, an info panel (Appendix 15) was introduced on the home screen describing how to use the dashboard.

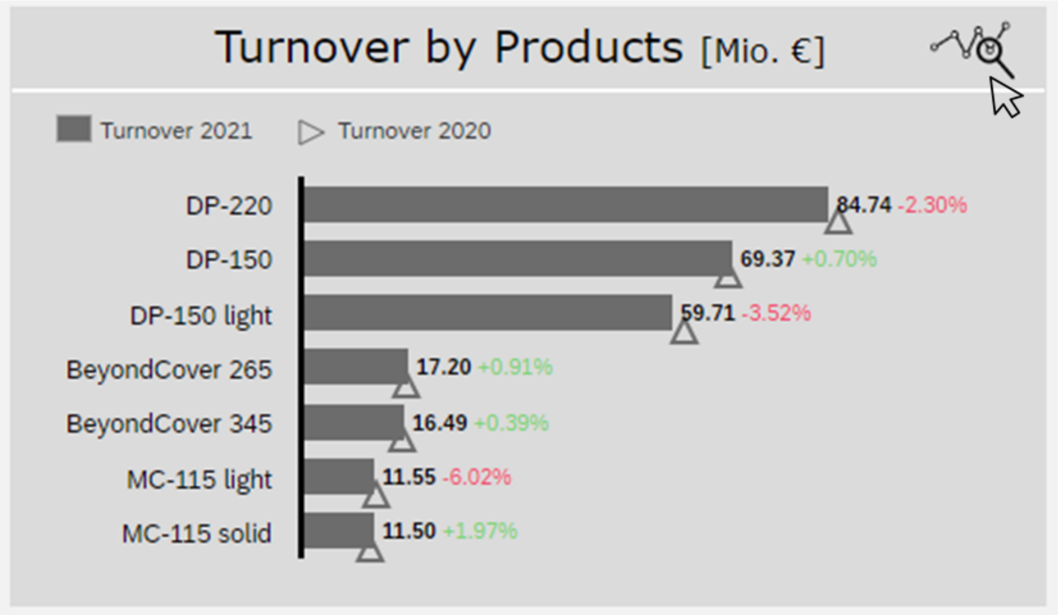
Navigation buttons

Other comments, also related to the last issue raised, are that the user could be better guided through the dashboard:

- “Geo-map does not provide additional information.” (User 4)
- “It may make sense to jump directly from the "Turnover by Products" and "Top 5 Customers by Turnover" charts. The way to filter first and then jump off is not quite intuitive. Maybe both functions (navigation to deep dive and filter) can be implemented on these charts.” (User 5)
- “Clicking on the diagrams is a bit confusing.” (User 6)
- “Navigation is not directly apparent to the user.” (User 9)
- “The user could be better guided through the dashboard (by icons, legends, comments).” (User 9)

For this reason, in addition to the info button, the dashboard has been provided with icons at the appropriate places, so that it is apparent to the user, at which point the analysis must proceed to the following dashboard. In the example shown in Figure 31, the user can click on the “Analysis” icon shown in the upper right corner to go to the next page for a detailed analysis.

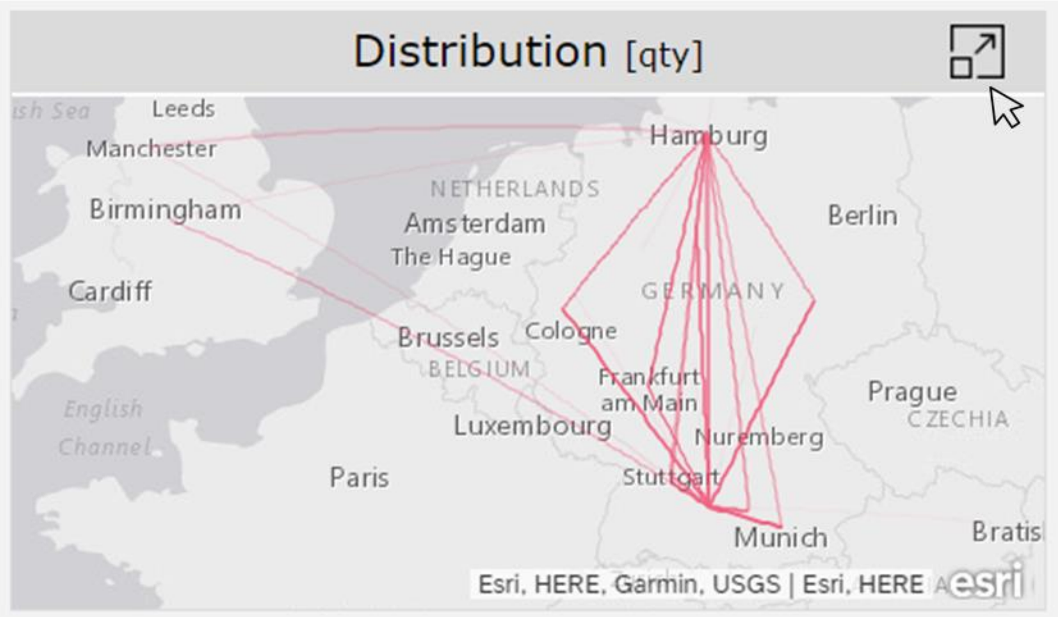
Figure 31: Analysis icon



Source: Own work.

In the other example in Figure 32, the user can click on the “Fullscreen” icon in the upper right corner to open the geo-map in a large format to better read the information. The enlarged view can be found in Appendix 16.

Figure 32: Fullscreen icon



Source: Own work.

Content enhancement

In addition, users also rated the importance of the mockup's content and provided their feedback:

- “Turnover by Products: Maybe two bars per product would be a little better to read the chart directly.” (User 5)
- “Turnover by Products: In addition, deviations to the previous year would be advantageous to quickly see how the sales of the products are developing.” (User 5)
- “Deep Dive: Probably it would look better if the KPIs are above the labels (3 KPIs: Turnover, Costs, and Profit).” (User 5)
- “Forecasts are relatively intensive if it comes to performance. Maybe it would be better to find the forecasts in deep dives rather than directly on the first management view (even if they look fancy).” (User 5)
- “Top 5 Customers by Turnover” – what’s the percentage of these Top 5 Customers? What is the rest? (Maybe another bar called “rest” would enhance the perspicuity of this specific key figure.” (User 7)
- “Turnover 2021 by Type of machine: What does the bar show? What’s the comparison? I just see -1,7% - but compared to what? Previous year? Plan value?” (User 7)
- “Timeline of key performance indicator development can be displayed only for the current quarter (overall view can be expanded in Deep Dive).” (User 9)

Again, employee recommendations were considered and integrated into the dashboard as much as possible. To compare the mockup with the subsequently developed dashboard, screenshots of the new dashboard have been included in the appendix (Appendix 17, Appendix 18 and Appendix 19).

Home button

A final recommendation was to integrate a home button:

- “Home button for deep-dive views, to get back to the overview.” (User 9)

This suggestion was also integrated into the solution concept. Figure 33 shows the "Home" button that the user can click to return to the home screen. This is especially useful when multiple dashboards are linked together. The analysis starts with a main high-level dashboard and then there are different types of filters and actions that can navigate to a secondary dashboard and eventually allow the end-user to navigate back to the original dashboard.

Figure 33: Home button

Source: Own work.

3.5.2 Interview results

In accordance with the methodology described in Chapter 2, the following section evaluates the DSR artifact developed in the case study. As previously described, the data collected during the evaluation were analyzed using qualitative thematic analysis. In the process, coding categories were developed inductively, using paraphrases, generalizations, and reductions. In doing so, certain themes emerged from the analysis of the data collected in the interviews. These will be discussed in more detail in the following points:

<u>Theme 1: Information usage</u>

Customers were first asked to describe what type of information they regularly use in their work. They were also asked about the importance of the data they use today, i.e., how important it is to analyze this information and how often this information is worked with. The answers were relatively similar. Most customers still rely mainly on historical data, i.e., current data that is available in a structured form, whereby unstructured data is becoming increasingly important.

- “Usually, it is almost always structured data, but there are also use cases with image data or geodata.” (User A)
- “In the company, we tend to have more historical data, so actual data, and predictive data is a slower issue that we're dealing with, but it's mostly still actual and planning data in a structured form. Big Data, which is unstructured data, is slowly coming up.“ (User B)
- “In our day-to-day business, we usually work with structured data, but there is also unstructured data.” (User D)

The analytical component of BI, i.e., the analysis of data to support decision-making processes, is becoming increasingly crucial for the company and, according to the respondents, is of immense importance and a significant task of their work.

- “In addition to integrating the data in the backends, we support all the departments with analytics, either we train the departments to work in Tableau themselves, as a self-service BI tool, we maintain the Tableau environments, the server, the desktop, etc., provide training, or if the department doesn't want to do it themselves, we also build the dashboard ourselves or have external partners that do it.” (User A)

- “The analysis is very important because this data is used for sales management to make decisions.” (User C)
- “The analysis is very important because when the key figures are presented to top management, it always leads to questions about why the development is the way it is, whether particularly good or bad. And you have to analyze the chain from top to bottom every day to explain the deviation.” (User D)

Theme 2: Software integration

Subsequently, it was essential to find out whether there is a need for an integrated dashboard at all. Here, interviewees were asked if they have information in different reports today that they would like to analyze/visualize in the same dashboard. It was also interesting to find out which BI tools they already have experience with or which tools they use in their company and whether they believe that using their preferred software tools would improve their work performance and increase their productivity. It turns out that the currently used dashboards have much catching up to do regarding their technical implementation and usability, and all respondents need to develop modern reporting with integrated and intelligent dashboards. That said, most companies are also in the process of reorganizing their structures, whether in individual areas or projects or, as described by User C, across the entire system:

- “Yes, precisely because we are converting the CRM system from SAP to Salesforce into the cloud, and we are doing this worldwide, which means that the entire reporting is also being restructured. In all its variants, the restructuring of the data, new basis, new dashboards, new tools, and new applications. And here we want to create reports that are mapped into an integrated dashboard system.” (User C)

Another respondent adds that integrating business applications with targeted analytics and content is becoming increasingly important and that the information mapped in a dashboard needs to be consolidated, not just juxtaposed, which means the logic behind each dashboard also needs to be transferred in some way.

The BI tools used in companies are very diverse and the use of multiple BI tools is becoming more and more standard.

- “SAC, Power BI and SAP BEx are the most common of these.” (User B)
- “We used to use SAP solutions (Lumira, Analysis for Office), and we also used a BI tool called Apteco.” (User C)
- “In our field, we use SAC and Tableau, in the company we also use Qlik.” (User D)

In addition, the use of the preferred software tools is of interest. The respondents believe that the use of preferred tools improves work management and increases productivity in any case. In particular, modern software solutions (self-service BI) for companies will be of great benefit here:

- “The changeover to Tableau, will, in my opinion, lead to a significant improvement in many areas. First of all, a lot more people will be able to work with it, whereas before it was just bundled in IT, so we will gain momentum, people handling it, visualization, and so on. We will become much faster and better.” (User C)

Another interviewee has a similar opinion. He explains that most BI tools today have a lot in common and that it does not primarily matter which tool you use when creating dashboards but that it is still important to work with the tool you know as an expert to gain new insights and analyze the data. He also believes that the concept of the integrated cascading dashboard fits the needs of the situation perfectly. There is a need for an integrated system and an interest in using different tools. He describes this as follows, which also leads directly to the next theme of using the new concept:

- “That is exactly the idea of this concept, that we say that the specialist department knows a tool very well and can work with it very well. Then it is a nuisance to have to deal with other tools. So, he can work in his department with the tool of his choice and if the management prefers another tool, then the management can still use another tool and navigate down. But the department can continue to use their preferred tool without having to learn another tool as well.” (User D)

Theme 3: Solution concept

Customers were asked questions about their perceived usefulness after the TAM and were asked if they would use the new solution concept (integrated cascading dashboard) in their work and whether they would find it helpful and complete their tasks faster compared to the existing dashboards. Their feedback on the advantages and disadvantages of the new solution concept was solicited. Except for User A, the other participants welcome the use of the new solution concept. User A believes that such an approach could lead to complexity with the linking of multiple BI tools. He thinks that companies should focus on one tool solution and build their dashboards on this basis. He also highlights the challenge of a unified database, saying that such a concept would be conceivable if one of the two tools adds significant value that one cannot achieve with the other, or can only achieve with an extension that incurs additional costs. He sees the data transaction from the SAC to the data warehouse as one possible use case, which he describes as follows:

- “You have shown that SAC has a forecasting function, Tableau can do that too, but if you now show that I can enter data that will be fed back, that will show even more the added value of your solution. Because Tableau can only do something like that with an extension. And that again costs money. But if I have SAC, then I paid for it, and it makes sense to use that.” (User A)

Users B, C and D consider that the concept in this form can also be used in practice. Guided analysis, storytelling, or focus reports, as others call them, create new knowledge. This presentation shares information broadly, and more information is achieved. User C adds, however, that management is used to rigid reports and has not yet learned how an interactive dashboard behaves, and this type will be very new to management.

- “What we are not used to at all at the moment is that the colleagues themselves sit in front and click a lot, which is also the strength here, storytelling in the reporting. That's something we're not used to yet and haven't learned yet. Because before, the reports were relatively rigid, there was a lot of reworking and PDF variants were sent by e-mail. So, this is a real change for management.” (User C)

Another point mentioned by a user was that sometimes it is necessary to visit several different dashboards to get all the information needed for a task. However, in this structure, it is possible to access all the information in the same report without leaving it. And the feeling of being in the same dashboard and not having to switch between reports is especially beneficial for lower management.

In addition to the major advantages, some disadvantages of the new concept are also discussed. Users are also unanimous in this respect. They believe the linked dashboard concept will impact performance, as this approach currently only works web-based and with unified data, which becomes a problem with Big Data.

- “It is currently only possible web-based, hence a point of criticism, and performance plays an important role. The dummy data is finite, and the performance is relatively good here, but when more information comes in, the performance goes down quickly.” (User C)
- “We also found that if you put everything on one database, i.e., top management and the absolute deep dive at the lower level, sometimes there can be data issues. When you have the all-encompassing solution and from a management perspective it's about aggregation, it's about computation, it's about fast availability, it's about performance, it's a challenge.” (User D)

Another disadvantage mentioned was the double maintenance and authorization concept, which might become a problem with this solution.

- “The authorization question would be the risk here because you have to maintain them twice in both tools.” (User A)
- “The authorization concept is already relatively painful with one BI tool, and that should not be forgotten here. Here, you certainly have double maintenance.“ (User D)
- “One disadvantage is the ongoing maintenance of two tools. You always have to see if you get the regular updates, etc. And when you have a change, it's not just in Dashboard 1 and Dashboard 2, but also in the transition from Dashboard 1 to 2.” (User D)

Theme 4: User experience

Customers were also asked to describe their perceived ease of use. To this end, again following the TAM, they were asked whether they found the integrated dashboard flexible and easy to use compared to previous dashboards. All respondents indicated that the solution concept can be used in the system in a way that is usable in their actual workflow. The overwhelmingly positive feedback shows that the previously created internal survey was successful and helpful and generalizes the feedback MHP employees provided from the survey.

One point to consider in connection with the user interface is the position of the filter function. With the current solution, the filters are located in the top area of the dashboard. This was not found to be particularly intuitive by half of the respondents. Respondents would have liked to see the filter function on either the left or right side.

- “From the feel of it, the filters were hidden for me, but if you know where they are, you can definitely find them. It doesn't feel as integrated into the dashboard to me.” (User C)
- “On most websites, I find filters either on the left or on the right. Intuitively, I would always search there. I don't find it quite as intuitive. It doesn't quite stand out from the header in my opinion.” (User D)

And one respondent found it difficult to navigate the levels and would like to see more information sections for people who do not use the system frequently explaining a little about what to do and how it works, which could be very helpful. Overall, the user interface of the solution concept was praised by all interviewees.

Theme 5: Decision-support

Another theme that has been at the center of answering the research question is the decision support that this concept follows. Therefore, interviewees were asked if this dashboard concept can help them in decision-making and whether they believe this concept can support decision-makers at all levels. Despite combining multiple BI tools into one integrated dashboard, all respondents viewed the storytelling capability positively and found this solution helpful for decision-making at all levels. One user commented that the drill-down functions and filter transitions create more in-depth information and cause and effect analysis when moving to the next level. Another user highlights the guided analysis approach and describes the advantage of storytelling, especially for users who do not use the tool frequently, as follows:

- “It is usually the case that a key user is someone who knows what he is doing, but you always have to put yourself in the role of the user who does not work with a dashboard every day and who is not familiar with the navigation of the SAC or the content, and you have to give him a way to get information, and you can do that very well with Guided Analytics.” (User B)

Another interviewee sees the possibility of a great exchange of information, especially in this structure. The reason for this is that the user finds it helpful if as many people as possible can work with the same dashboard so that the analysis remains at the same level. The understanding is the same between the top and middle management and between middle and lower management.

However, respondents also pointed out that it is not only important to provide employees with the tools, but also to guide them to use these tools. In doing so, management must follow suit and drive the change. This is often underestimated. In addition, they indicated that decision-making is highly dependent on content. Such a structure alone would not be sufficient for decision-making. That is why storytelling is very important to them, in addition to linking to various BI tools. When asked if they already use similar dashboards, they therefore always answered yes, but only partially.

- "For sales pipeline analysis, we have a similar dashboard that goes from the top management level to the operational level and back to the base system. That goes in the same direction. Everyone is working on, let's say, an enterprise dashboard or a process-oriented dashboard at the management level, where the key KPIs are shown first and then details are shown with drill-downs. We have such dashboards in different areas." (User A)
- "We have built such in the construction in which we go into several levels. The first approaches are there, while the direct connection with parameters is not yet, but that is definitely a point that will be subject." (User B)
- "Dashboard with drill-downs so enters in more levels that definitely, but with multiple tools that unfortunately not." (User C)
- "We have dashboards where we do storytelling, but we haven't linked it in that form yet." (User D)

The structure of a dashboard in the form of storytelling is common, but in the linked form, it is still foreign to everyone. However, practical use cases in the company are conceivable and the interest in the new solution concept (integrated cascading dashboard) is high, which is reflected in the additional demand for a presentation and the request for further discussion.

3.6 Business Value Analysis

In addition to the areas of application, possibilities and functions, the costs also play a role in the acceptance of the solution concept. Therefore, a brief business value analysis is conducted in this chapter of the master thesis. Since SAP's pricing for its software is very complicated and is partly determined on a customer-specific basis, the following calculation does not include SAP costs and calculates additional charges or the additional savings of Tableau licenses. The use case described in the introduction, which was also the consideration for the topic of the master thesis, serves as an example. This scenario involves a company that uses both SAC and Tableau as BI tools in its enterprise and is now asking itself whether it should standardize all of the BI software in its enterprise and rely on one vendor, namely SAP, or continue to offer both tools but create an integrated solution as presented in the master's thesis. In order to be able to map this example for a large number of companies, various weightings and user groups, as well as numbers, are defined and included in the calculation. For the conversion to SAP, it is assumed that the company hires a service provider to convert all dashboards used in the company to SAC. An average hourly rate of €120 and a working time of 50 working days is estimated for a project. It is important to note that here, again, prices and workload cannot be precisely determined and can vary greatly depending on requirements. Assuming an average of five projects, this results in an expense of approximately 240.000 €. In contrast, the Tableau license costs saved or, if retained, the ongoing license costs are highlighted in Table 6.

Table 6: Cost matrix Tableau

User type	Share	Costs Tableau
Creator	15 %	70 € per month
Explorer	20 %	42 € per month
Viewer	65 %	15 € per month
	Company size:	250 Employees
	Number of users (20%):	50 Employees
Total cost per month:	50 users	1.432,5 €
Total cost per year:	**50 users**	**17.190 €**
	Company size:	1000 Employees
	Number of users (20%):	200 Employees
Total cost per month:	200 users	5.730 €
Total cost per year:	**200 users**	**68.760 €**
	Company size:	5000 Employees
	Number of users (20%):	1000 Employees
Total cost per month:	1000 users	28.650 €
Total cost per year:	**1000 users**	**343.800 €**

Source: Own work.

Depending on the size of the company, several alternatives can be considered. Especially for small companies or for large companies with manageable licenses for Tableau, it is not worthwhile to standardize all BI software in the company and rely on one provider. In place of this change, they could bear the license costs for several years and switch to the new solution approach. On the other hand, it might be economical for substantial companies to try to avoid licensing costs for multiple BI users since they would amortize the changeover within a year. Nevertheless, an integrated approach such as the one presented in this paper may be an option for most companies, even for very large companies, where licensing costs exceed the cost of the standardized solution because it is known that most companies have multiple BI tools in use, which also emerged from the survey. And for most companies, the non-monetary benefits, such as using the preferred software tools or creating a common understanding between management levels, are more critical. Therefore, the consideration of introducing such a concept should not be measured primarily in terms of monetary aspects.

3.7 Guidelines for Implementation

As mentioned earlier, this chapter describes detailed instructions for transferring filter parameters. Three different types of scenes are mapped here, namely transferring filter parameters from Analytic Application to a Story, from Story to Tableau, and, as an excursion, from Analytic Application to Tableau.

Scenario: Analytic Application → Story

In this scenario, the parameters are passed via the SAC Open Story URL API. This allows stories to be opened directly via URL in a browser and filtered with additional parameters. Note that there are a total of three required parameters that must be defined before filters can be applied to a story.

Scripts in the analytic application are displayed on the left side of the analysis designer editor. When you hover the mouse cursor over the corresponding widget names, the “fx” icon appears, and clicking it opens the script editor. You have two options on how to run the scripts. Either by active selection or by changing the result. Especially when filtering within a chart, the script is often selected when the result changes, so you are taken directly to the next level. In this example, however, the scripts are used on selection, which has the advantage that multiple items can be filtered and then executed.

The “NavigationUtils.openStory()” command allows you to navigate from an open analytical application to another page of a story. This command requires two mandatory parameters: the story ID and the page ID. By clicking Ctrl+Space, a selection area opens where you can directly select the target story without knowing the IDs. The script API takes the IDs of the pages in a story and opens the expected page in a new tab. If the page should be opened in the same tab, the new Tab parameter must be set to “false”. For the story created in the master thesis, i.e., the second level of the dashboard, the command looks like the following:

```
NavigationUtils.openStory("A8816787CCB12CD9A1C5A92E79BD5A32", "199780ac-b73e-40f9-be8e-e64f24e72ada", false);
```

Parameters must be added to this command so that parameter values can also be passed. It is necessary to specify the model to which you want to apply the filter (key: f<XX>Model), the dimension to which you want to apply the filter (key: f<XX>Dim) and the values by which you want to filter (key: f<XX>Val). <XX> within a key is a freely selectable twodigit number and is used to indicate which parameters belong together. This is especially important if more than one filter is passed. Please note that the parameters passed in a URL must be encoded. A list of encoding references can be found in Appendix 24. The “UrlParameter.create” command can be used to create the corresponding parameters. The model information is used to determine the model ID. The following URL shows the model information for all stories that can be accessed with one' tenant:

https://<TENANT>/api/v1/stories?include=models

The ID from the list (see Figure 34) is added to the command. In our example, it looks like this:

Figure 34: Search for Model ID


```
Story","description":"","createdBy":"USER040","id":"83B09F87CCB322515CF13453AD75AA7F","created":"2022-05-29T09:19:24.519Z","changed":"2022-0
13T15:20:54.211Z","isTemplate":false,"isSample":false,"models":
[{"description":"","id":"t.X.C4I6KXJZMI7X21ESIR1D39SLC0:C4I6KXJZMI7X21ESIR1D39SLC0","isPlanning":true}],"changedBy":"USER040","openURL":"/sa
enants/201d4/bo/story/83B09F87CCB322515CF13453AD75AA7F"},{"name":"Forecasting Educational Expenditure and
Revenue","description":"","createdBy":"GHUELSKAMP","id":"83B1D2FF2C4065F220B74FCD91F06781","created":"2020-08-17T13:52:07.203Z","changed":"2
17T15:15:47.677Z","isTemplate":false,"isSample":false,"models":
[{"description":"","id":"t.X.C3IMKJL8JOFXO1RWFELRXWNLDS:C3IMKJL8JOFXO1RWFELRXWNLDS","isPlanning":true},
{"description":"","id":"t.X.C4GBT0EM303QI4NQJ0X7V3J20W:C4GBT0EM303QI4NQJ0X7V3J20W","isPlanning":true},
{"description":"","id":"t.X.CNE4ZT4FV2KMPZ42LHTQ2S4JK:CNE4ZT4FV2KMPZ42LHTQ2S4JK","isPlanning":true}],"changedBy":"USER003","openURL":"/sap/f
nts/201d4/bo/story/83B1D2FF2C4065F220B74FCD91F06781"},{"name":"SAP__FI_CS_ACT_CONSOLIDATED_RPT_BOOK_ALL","description":"Actual consolidated
for Consolidation","createdBy":"USER017","id":"83DA7AE2FF30367595F7866C18E58225","created":"2022-04-26T09:56:30.769Z","changed":"2022-04-
26T09:56:30.769Z","isTemplate":false,"isSample":false,"models":[{"description":"Consolidation Data Model w/o Reporting Rule","externalId":"q
[2CCCSMATRIXRPT10Q]","id":"t.S.SAP__FI_CS_DATA_WO_RPTRULE:SAP__FI_CS_DATA_WO_RPTRULE","remoteConnection":
{"connectionType":null,"systemType":null,"id":"SAPEMC","scpAccount":null},"isPlanning":false},{"description":"Consolidation Data Model with
Rules","externalId":"query:[][][2CCCSMATRIXRPT30Q]","id":"t.S.SAP__FI_CS_DATA_W_RPTRULE:SAP__FI_CS_DATA_W_RPTRULE","remoteConnection":
{"connectionType":null,"systemType":null,"id":"SAPEMC","scpAccount":null},"isPlanning":false}],"changedBy":"USER017","openURL":"/sap/fpa/ui/
1d4/bo/story/83DA7AE2FF30367595F7866C18E58225"},{"name":"Second level","description":"Deep Dive
view","createdBy":"USER03","id":"84A01787CCB1491499939F84A992D835","created":"2022-05-23T06:46:29.969Z","changed":"2022-06-
01T10:59:03.444Z","isTemplate":false,"isSample":false,"models":
[{"description":"","id":"t.X.CB3V78P29LFYWU9QPWS1E9PPTS:CB3V78P29LFYWU9QPWS1E9PPTS","isPlanning":true},
{"description":"","id":"t.X.CDQZ7T63RT42HSJTJ8L7R9ODMO:CDQZ7T63RT42HSJTJ8L7R9ODMO","isPlanning":true},
{"description":"","id":"t.X.CES5VA21V7STSUDWGU1F2Q3280:CES5VA21V7STSUDWGU1F2Q3280","isPlanning":true}],"changedBy":"USER03","openURL":"/sap/
ants/201d4/bo/story/84A01787CCB1491499939F84A992D835"},{"name":"Präsi_Final_Final","description":"Use-Case
2","createdBy":"GHUELSKAMP","id":"8510AFC3E9D85947D0E8A93A620F736","created":"2020-07-29T19:56:29.699Z","changed":"2020-07-
30T12:43:27.468Z","isTemplate":false,"isSample":false,"models":[{"description":"UseCase
2","id":"t.9.C2MQUYKEQPPOH1QHJWFHFIO8OW:C2MQUYKEQPPOH1QHJWFHFIO8OW","isPlanning":true},{"description":"Bilanzdaten und
Ertragslage","id":"t.9.C6r7432fvuhz0kylyazjb6k074:C6r7432fvuhz0kylyazjb6k074","isPlanning":true}],"changedBy":"USER029","openURL":"/sap/fpa/
/201d4/bo/story/8510AFC3E9D85947D0E8A93A620F736"},{"name":"Planning Training
Story","description":"","createdBy":"GHUELSKAMP","id":"85B3F28170932CEB304DE3078A0E4AB4","created":"2021-09-21T08:41:38.897Z","changed":"202
21T10:04:42.244Z","isTemplate":false,"isSample":false,"models":
[{"description":"","id":"t.X.Cqt22pwt1iggvday88czmnv9c:Cqt22pwt1iggvday88czmnv9c","isPlanning":true}],"changedBy":"USER002","openURL":"/sap/
ants/201d4/bo/story/85B3F28170932CEB304DE3078A0E4AB4"},
{"name":"Ebene_4_Transporte_LiSc","description":"","createdBy":"USER040","id":"87213281536874969806DFAEAD2E459A","created":"2022-02-
24T09:18:41.446Z","changed":"2022-02-25T14:47:11.567Z","isTemplate":false,"isSample":false,"models":
[{"description":"","id":"t.X.CN4UESMPCPL5F4AHGD2XM2BCW:CN4UESMPCPL5F4AHGD2XM2BCW","isPlanning":true}],"changedBy":"USER040","openURL":"/sap/
ants/201d4/bo/story/87213281536874969806DFAEAD2E459A"},{"name":"SAP__HR_ANA_EC_OHP_PLAN_HC","description":"Analysis Plan
(HC)","createdBy":"GHUELSKAMP","id":"879F62F8FD6DDEE32CECFE9F98BB5EF7","created":"2021-09-07T07:12:13.313Z","changed":"2021-09-
13T09:23:04.700Z","isTemplate":false,"isSample":false,"models":[{"description":"SAP Human Resources: Operational Headcount Planning - Job
Code","id":"t.A.Cau2i7pxua1stqdwa48nuuwz5s:Cau2i7pxua1stqdwa48nuuwz5s","isPlanning":true}],"changedBy":"USER052","openURL":"/sap/fpa/ui/tena
```

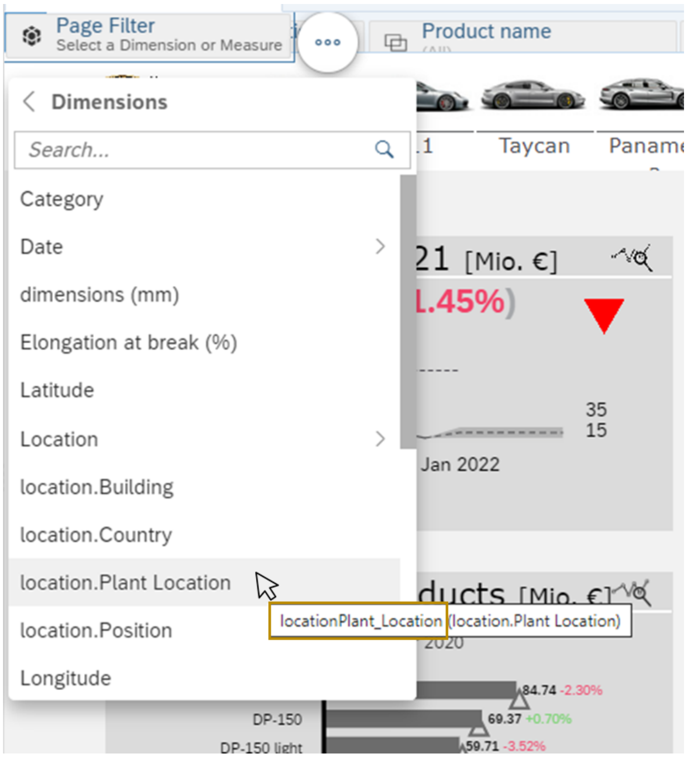

Source: Own work.

NavigationUtils.openStory("A8816787CCB12CD9A1C5A92E79BD5A32", "199780ac-b73e-40f9-be8e-e64f24e72ada",

[UrlParameter.create("f01Model","t.X.CB3V78P29LFYWU9QPWS1E9PPTS:CB3V78P29LFYWU9QPWS1E9PPTS")], false);

The next step is to add the dimension ID. Only the technical ID of the dimension is needed, which can be found by hovering the mouse cursor over the corresponding parameter to be filtered. In this example, the dimension ID of the “Plant location” dimension, as shown in Figure 35, is searched for and included in the command.

Figure 35: Search for Dimension ID



Source: Own work.

NavigationUtils.openStory("A8816787CCB12CD9A1C5A92E79BD5A32", "199780ac-b73e-40f9-be8e-e64f24e72ada",
[UrlParameter.create("f01Model","t.X.CB3V78P29LFYWU9QPWS1E9PPTS:CB3V78P29LFYWU9QPWS1E9PPTS"),
UrlParameter.create("f01Dim","locationPlant_Location")], false);

The last step is to specify by which values you want to filter. Since one does not want to filter by a predefined value, it is necessary to address the filtered values in an input control or in a chart and filter based on them. In the first step, a variable is defined, and the values of input control or a chart are selected:

Input Control:
var xxx = InputControl_1.getInputControlDataSource().getActiveSelectedMembers();

Chart:
var xxx = Chart_1.getDataSource().getDataSelections();

Here the command outputs the values in the form of a dictionary; therefore, the ID must be read and reformatted accordingly. The dictionary for "Plant location" initially looks as shown in Figure 36.

Figure 36: Search for Value ID

```
▼ (2) [{…}, {…}]
  ▶ 0: {dimensionId: '', id: 'Hamburg', description: 'Hamburg', displayId: 'Hamburg'}
  ▶ 1: {dimensionId: '', id: 'Ulm', description: 'Ulm', displayId: 'Ulm'}
    length: 2
  ▶ [[Prototype]]: Array(0)
```

Source: Own work.

To ensure that single and multiple selections are also transmitted correctly, the filter values are passed in coded form in an if loop. The transcription of the transmission of the filter parameter for the filter "Plant location" looks as follows:

```
var location = InputControl_1.getInputControlDataSource().getActiveSelectedMembers();

var location_filtervalues = "%5B%22";

for (var a = 0; a<location.length; a++) {
        if (a === (location.length - 1)){
                location_filtervalues = location_filtervalues + location[a].id + "%22%5D";
        } else {
                location_filtervalues = location_filtervalues + location[a].id +
                "%22%2C%22";
        }
}
```

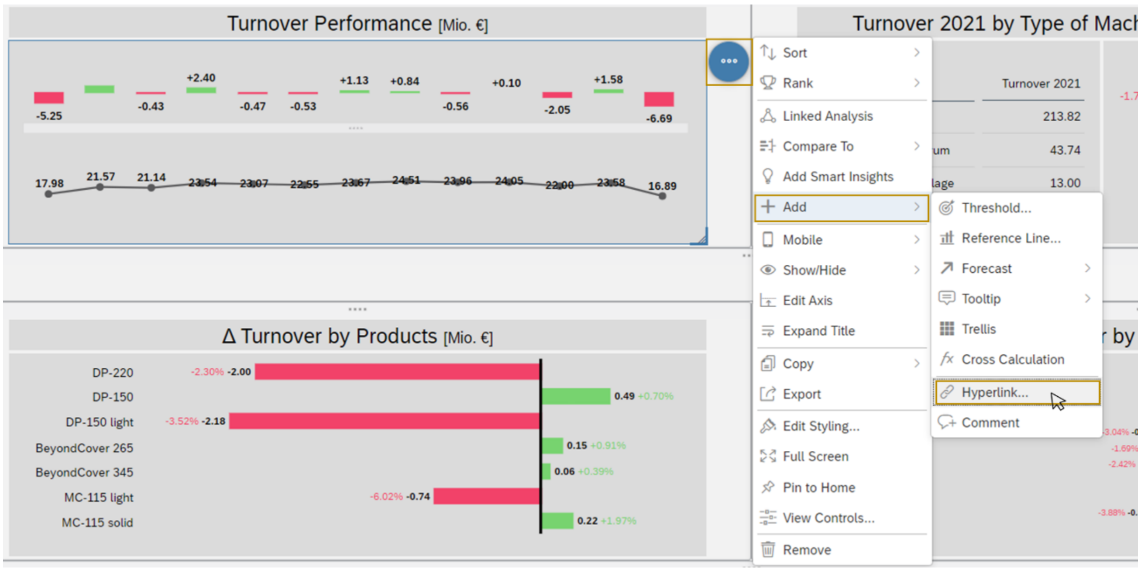
Finally, the variable of the filter values must be added to the navigation script API. The final command becomes as follows:

```
NavigationUtils.openStory("A8816787CCB12CD9A1C5A92E79BD5A32", "199780ac-b73e-40f9-be8e-e64f24e72ada",
        [UrlParameter.create("f01Model","t.X.CB3V78P29LFYWU9QPWS1E9PPTS:CB3V78P29LFYWU9QPWS1E9PPTS"),
        UrlParameter.create("f01Dim","locationPlant_Location"),
        UrlParameter.create("f01Val",location_filtervalues)], false);
```

Scenario: Story → Tableau

In our example to Tableau, the filter transfer from a story to an external URL is performed by hyperlinks. Please note that in this form, only one value per dimension can be passed and mapped in the target architecture. To access the hyperlinks, select the chart and under detailed actions, first, select Add and then Hyperlinks, as shown in Figure 37.

Figure 37: Display hyperlink function



Source: Own work.

By clicking on the Hyperlink tab, a section "Hyperlink" will be displayed on the right side of the screen. From here, one has several options to insert hyperlinks. In this example, choose the link to an external URL. In the next step, one enters the URL and in order to link a dimension to this URL, one selects the corresponding dimension from the list of all available dimensions under the option "Labels". SAC opens the hyperlinks in the same tab by default. If one wants to open the hyperlink in a new tab, one has to check the "Open in new tab" box. In the last step, the following addition must be added to the Tableau hyperlink "&Dimension ID= identifier". The hyperlink for passing the filter parameters for the "Plant location" filter looks like the following:

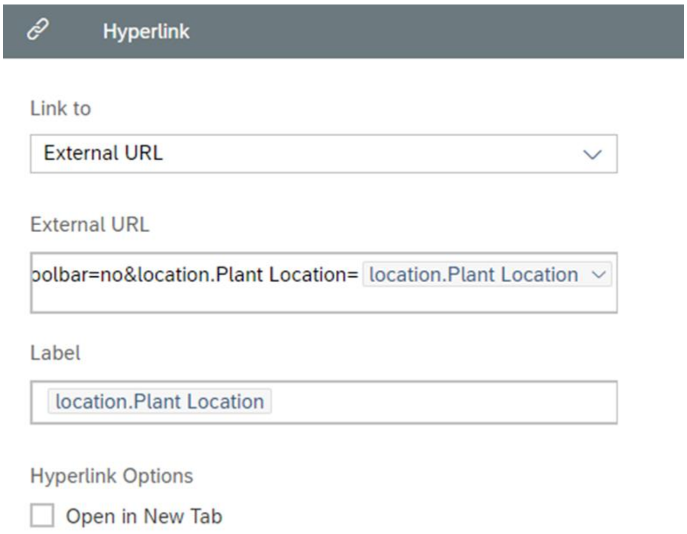
https://dub01.online.tableau.com/#/site/tableaumhp/views/third_level/Dashboard1?location.Plant Location=location.Plant Location

To keep the user interface as similar as possible between the different tools, Tableau's navigation pane and toolbar, which are displayed by default, can be hidden in the embedded view. To hide the navigation pane, ":embed=yes" is inserted after the URL, and to hide the toolbar, ":toolbar=no" is inserted after the URL. Again, the input URL must be set in encoded form. For example, ":embed=yes" must be encoded as %3Aembed=yes. The extended URL will look like the following in our example:

https://dub01.online.tableau.com/#/site/tableaumhp/views/third_level/Dashboard1?%3Aembed=yes&%3Atoolbar=no&location.Plant Location=location.Plant Location

In the Designer view, the input looks as shown in Figure 38.

Figure 38: Hyperlink settings



Source: Own work.

<u>Scenario: Analytic Application → Tableau</u>

Another way to transfer parameters to the target architecture is to link the application to Tableau. The advantage of this way is that, as in the first scenario, multiple values of the same dimension can be recorded and transmitted. As in a story, the hyperlink is extended by the addition "&Dimension ID= identifier", but flexibly handled with a variable. The “NavigationUtils.openUrl()” function can be used to navigate from an open analytical application to an external URL. The parameter "new Tab" must also be set to "false" here if the page is to be opened in the same tab. So that single and multiple selections can also be transmitted correctly in this case, the filter values must be passed in an encoded form in an if loop. The transcription of the transmission of the filter parameter for the filter "Machine" looks as follows:

```
var machine= InputControl_1.getInputControlDataSource().getActiveSelectedMembers();

var machine_filtervalues = "Machine=";

for (var j = 0; j< machine.length; j++) {
        if (j === (machine.length - 1)){
                machine_filtervalues = machine_filtervalues + machine[j].id + " ";
        } else {
                machine_filtervalues = machine_filtervalues + machine[j].id +
                "&Machine=";
        }
}
```

This variable is then passed as a value to the original command, as follows:

```
NavigationUtils.openUrl("https://dub01.online.tableau.com/#/site/tableaumhp/views/third_level/Dashboard1?"+machine_filtervalues,false);
```

4 DISCUSSION OF FINDINGS

In this thesis, the research question investigated how the use of different BI software can be transformed into an integrated concept that supports decision-making at all management levels. In response to the research question, the next step is to look for success factors or conditions that need to be considered or met when implementing integrated dashboards in order for the decision-making process to be a complete success, both in theory and in practice. Furthermore, to be able to verify the applicability of the success factors presented, a critical examination of the external validity of the results is carried out.

4.1 Success Factors

The evaluation results of the DSR artifact developed in the case study are used as an empirical foundation for the definition of the success factors. The result from this is as follows:

First of all, companies must be aware that introducing an integrated concept in this form is only possible if the entire changeover begins at the backend since a uniform database, i.e., data quality, is a fundamental prerequisite for merging multiple BI software into a unified environment. This means that linking two dashboards that were created independently will not work. Furthermore, even if both access a unified data set, the business logic in the front-end tools may be different, which alone can be a barrier to the integration. Integration is therefore fundamentally possible in new projects if all business areas are involved from the beginning and uniform business logic is applied across all levels. However, it was also noted that the dashboards currently in use have much catching up to do and that companies see the need to develop modern reporting with integrated and intelligent dashboards that make the topic very practical.

It has also been shown that companies only accept the concept of an integrated cascading dashboard if it works technically and adds additional value. The combination of multiple BI tools in one integrated dashboard and the ability to storytelling is at the core of this concept and the aid to decision-making at all levels. This structure allows for a great exchange of information and more in-depth information and cause-and-effect analysis. Linking eliminates the need to visit different systems to retrieve all the required information for a task. In addition, understanding between upper and middle management and middle and lower management is not affected because the analysis is performed consistently by using many disciplines. Nevertheless, the choice of BI tools used is also crucial. Companies may reject the concept and opt for one tool solution if one BI tool does not have a feature that adds significant value compared to the other. Here, too, it makes sense to exchange ideas with other departments that use different tools and first to consider which tool makes sense so that it can be aligned and built accordingly. Thus, the application of the new solution concept can be welcomed.

Another factor that must be met for this concept to be applied in practice is that the user experience must also be in line, i.e., the dashboard must be clear, concise and logically structured, and the transition to the next tool must be smooth. An integrated solution is defined not only by the content of the dashboard but also by the way the information is communicated. If users get the impression that they are in a different tool during the transition, they simply will not benefit from this concept. That would negate all the advantages of the dashboard and would not offer any added value. The design principles, as with all dashboards, are essential to the design of this dashboard. The most important information should be visibly presented in an easy-to-navigate format and structured in the same way regardless of the tool used. However, this is not always easy to realize. Implementing a dashboard with a uniform look in SAC Analytic Application and SAC Story alone is a major challenge. And creating the same look in another BI tool requires a lot of work.

The performance issue is also a factor that became apparent in the evaluation of the DSR artifact. A common problem that data analysts and report users face is slow dashboards that make the user wait for charts and reports to load. Especially in a web-based environment, using a live connection to connect to databases with millions of records can be challenging. To solve this problem, many performance-enhancing techniques and features can be implemented. Again, backend measures such as improving the data model or optimizing the tables in the database can be used first to eliminate performance problems. In addition, best practices can also be followed in the design of the dashboard to optimize performance. To name a few, global filters can be used, unnecessary calculations can be avoided, or unused steps can be removed, which has also been considered in this solution design. Hence, this is an issue that should not be taken lightly and should be considered in the design of the dashboard. Since the topic of web-based solutions and real-time data also came up here, it is important to emphasize at this point that access to and analysis of information will improve decision-making, as it means having access to the most up-to-date data, less guessing about the current situation or waiting for data to be collected, and also being able to take the necessary actions in a timely manner.

Another important factor that must be taken into account during implementation is the authorization/permission concept. With the new concept, many people from different areas of the company will be able to access the dashboard. It must therefore be ensured that users can only access the functions and data that are required to perform their tasks. Data access rights can be defined in both SAC and Tableau, which is already a real struggle for most organizations with their existing dashboard based on a single BI tool. With the introduction of an integrated approach that relies on multiple BI tools, the authorization concept becomes an additional task that poses a major challenge for most companies. Double maintenance also becomes a new task. Not only do both dashboards have to be cared for and maintained, but also the transition from one to the other has to be serviced. These two new tasks, especially the first one, will be the main drawbacks of this concept, which will play an important role in the decision of companies whether to use the new concept or not.

Another topic that is important for all new developments or restructurings, but should not go unmentioned here, is the topic of change management. From most interviews and also from conversations with internal employees, it appears that most companies today have many different BI tools in use, most even have several at the same time, but many employees still fall back on their previous reporting system, i.e., Excel spreadsheets, and do not take advantage of the options offered. It is not only important to provide people with the tools but also to guide them in their use, which is a widespread problem and remains so in the new approach. To ensure broad acceptance and implementation of the new concept, change management must therefore take place under the leadership of top management. Top management must actively promote the use of BI tools, as this is the only way to create a unified BI environment that supports decision-making at all management levels. Table 7 summarizes the findings that guide successful integration.

Table 7: Success Factors

1.	The entire changeover has to start in the backend. A uniform database, i.e., data quality, is the basic prerequisite.
2.	The concept of an integrated cascading dashboard will be accepted if it works technically and offers added value.
3.	For the overall concept to be used in this way, the user interface must also fit; in particular, a smooth transition to the next tool is important.
4.	The issue of performance is a very big challenge.
5.	Authorization/permission concept becomes an additional task, which is a major challenge for most companies.
6.	To ensure that this is also widely accepted and implemented, change management must take place. Under the leadership of top management.

Source: Own work.

The results clearly show that most companies are aware of the fact that building a data-driven organization is very important to their business success, and that collecting, managing and analyzing large amounts of data is a major challenge. They understand that deep insights are required to make the right information-based decision and are willing to adopt new solutions. Merging multiple BI software integrates all data insights across the enterprise and enables strategic discussions across all business decisions. The concept can enable companies to accelerate and improve decision-making processes, thus generate new revenue and gain a competitive advantage over their competitors. In this context, the success factors serve as a guideline for successful integration into a unified BI environment as a basis for strategic decisions.

4.2 Critical Reflection

Concerning the external validity of the results, i.e., the degree of generalizability of the results across social settings, the methodological approach is critically analyzed. In the preparation of the master thesis, the DSR approach was used as an overarching research framework. This has proven to be a scientifically and methodologically accepted approach that has a highly positive impact on the external validity of the success factors. It should be noted, however, that the DSR approach is an iterative approach, and further development and evaluation cycles should follow, which could increase the representativeness of the results in the long term. This could be done after the internal survey and after the interview with the customers. However, since this would go beyond the scope of the master's thesis, the iteration was dispensed with at this point and the findings were transferred to the next phase. In addition, as part of the DSR approach, the case study proved to be a useful evaluation basis of the design artifact to answer the research question of this study. The single-case design of the case study with a multi-source data collection approach realized step-by-step first through a mockup and then as a prototype also achieved the desired effect of testing the developed artifact against the fictitious use case and demonstrating the relevance of the success factors. It should also be noted here that small sample size, i.e., the number of participants in the internal survey and the number of participants in the interviews, was used to generate the necessary data, which should be interpreted carefully since in such cases, a small value may result solely from sampling effects and may not indicate a real problem. It would be very interesting to create a working version of the integrated cascading dashboard since not much has been written in the literature about how to transfer different BI software into an integrated concept that supports decision-making at all management levels. Therefore, the research at this point is not yet complete, although the developed research methodology has led to valid and representative results and should be iteratively developed further on the basis of further research projects in order to improve the insightful and validity findings of the identified success factors.

CONCLUSION

In the age of digitalization, the importance of BI is more than ever an essential element to increasing the competitiveness and performance of companies and making well-founded business decisions. This forces companies to become data-driven organizations since data and its use have become essential for improving products and services and supporting new business models. In particular, the analytical component is becoming increasingly important in the context of Big Data. In this regard, combining multiple BI tools into one integrated dashboard helps organizations to maintain their preferences in software selection and allows all members of an organization to move from isolated data islands use to a fully data-driven culture that provides the foundation for appropriate strategic decision-making.

However, dashboard integration depends on several factors explored in this thesis, specifically in the context of using different BI tools in an integrated approach that supports decision-making at all management levels. At the beginning of the study, a critical literature review was conducted on the theoretical foundations. Examining BI and dashboards as the two sources of knowledge forms the basis for the subsequent development of the DSR artifact. Namely, the basis to achieve the research goal of developing a dashboard concept based on SAC and Tableau and evaluating its feasibility and acceptance. Initially, a mockup was developed and opinions on the subject of the user interface were gathered in an internal survey among MHP employees. Subsequently, the findings from the survey were transferred to the solution design and the prototype was implemented. Interviews were then conducted with MHP customers to obtain in-depth opinions that form the basis for answering the research question of how the use of different BI software can be transformed into an integrated concept that supports decision-making at all management levels. Finally, a guideline and business value analysis were created for further practical applications and projects. The success factors or conditions that must be considered or met provide the framework for successful integration. The results of this work show that successful integration is only possible if solid uniform database is ensured. Linked analytics with multiple tools that enable storytelling then creates broad and deeper insights into data that generate value from data to drive decisions across all management levels. The importance of user interfaces is also being addressed by many companies, with issues such as performance, authorization concepts and change management also needing to be considered and posing challenges during implementation.

The overall results of the work are aimed at two different target groups. On the one hand, researchers can use this work as a starting point for further research projects, since the topic is quite emerging and there is relatively limited literature on it, and since this work, like any research project, is subject to certain research limitations. This work provides a rich starting point for further research approaches, both in terms of applied research methodology and research results that may be useful to other researchers by providing a framework for studying merged BI software. On the other hand, companies can use the developed critical success factors in combination with the prototype as a blueprint for solving similar use cases. Above all, companies that no longer see digital transformation merely as a challenge but want to use it as an opportunity for their own business can use this solution to offer a broad and flexible decision-making aid and user-friendly software support to ensure acceptance and openness to future requirements.

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APPENDICES

Appendix 1: Povzetek (Summary in Slovene language)

Pomen BI še naprej narašča zaradi digitalne preobrazbe in povečanja količine podatkov, analitična komponenta pa postaja vse pomembnejša. Pogosto pa oddelki v podjetju razvijajo lastne rešitve za poročanje, ker podpora oddelka za IT ni mogoča, ker zmogljivosti oddelka za IT niso zadostne ali ker sistemske rešitve niso na voljo. To pogosto vodi v heterogena BI okolja, v katerih so podatki redundantni, kar povzroča visoke stroške vzdrževanja. Tudi če je podatkovna osnova enaka, se v poročilih včasih uporabljajo različne poslovne logike, kar vodi do različnih rezultatov in s tem do pomanjkanja preglednosti. Zamisel o združevanju več orodij BI v eno integrirano nadzorno ploščo lahko pomaga ohraniti preference pri izbiri programske opreme in omogoča organizaciji preiti od izolirane uporabe podatkov k popolnoma podatkovno usmerjenem okolju, ki je podlaga za ustrezno strateško odločanje.

Cilj tega magistrskega dela je razviti koncept kaskadne nadzorne plošče, ki temelji na SAC in Tableau, ter oceniti njegovo izvedljivost in sprejemljivost, s čemer bi lahko odgovorili na raziskovalno vprašanje, kako je mogoče uporabo različnih programov BI preoblikovati v integriran koncept, ki podpira odločanje na vseh ravneh upravljanja. Za dosego tega cilja je v diplomski nalogi zastavljenih več podciljev. Prvi podcilj je proučiti teoretične temelje BI in nadzornih plošč, ki bodo služili kot osnova za oblikovanje teme, na kateri temelji raziskava. To bo tudi podlaga za izbiro programske opreme BI za analizo primera uporabe. Drugi podcilj je razviti koncept integrirane nadzorne plošče z združitvijo več orodij BI v okviru študije primera. Poudarek pri uvajanju nadzorne plošče je na uspešni integraciji v enotno okolje BI kot podlago za strateško odločanje. Tretji podcilj je oceniti razviti prototip s testiranjem uporabnikov in intervjuji, da bi preverili njegovo ustreznost in ga izboljšali s praktičnimi spoznanji. Zadnji podcilj je pripraviti smernice in analizo poslovne vrednosti za nadaljnje praktične aplikacije in projekte.

Magistrsko delo je nastalo v sodelovanju z nemškim svetovalnim podjetjem MHP Management- und IT-Beratung GmbH. Kot splošni raziskovalni okvir disertacije je za razvoj artefakta uporabljen raziskovalni pristop znanstvenega oblikovanja (angl. design science research, DSR).. Da bi zagotovili potrebno ustreznost pristopa DSR, se kot empirična raziskovalna metoda izvaja pojasnjevalna študija primera. Podatki, zbrani v študiji primera z notranjimi anketami in zunanjimi intervjuji, so bili analizirani s kvalitativno tematsko analizo in uporabljeni kot podlaga za teoretični prispevek. Rezultati, ki vključujejo uporabo informacij za poslovno odločanje, integracijo programske rešitve in koncept rešitve, ponujajo teoretični in praktični prispevek ter odgovor na raziskovalno vprašanje. Kritični dejavniki uspeha predstavljajo hevristična priporočila za razvoj, zasnovo in uvedbo celostnega pristopa k rešitvam z uporabo različne programske opreme BI za podporo odločanju na vseh ravneh upravljanja. Ta vključuje poenoteno bazo podatkov, funkcionalnosti rešitve, primeren uporabniški vmesnik, učinkovito delovanje ter najenostavnejšo možno avtorizacijo. Na ta način je mogoče zagotoviti izvedljivost in povečati sprejemljivost integriranih nadzornih plošč v podjetjih.

Appendix 2: Survey overview

Master Thesis - Tahsin Atmaca
June 01, 2022 - User Experience Questionnaire (UEQ)

Dear user,

the following survey is a part of the evaluating phase of my master thesis: “Merging multiple business intelligence software to provide a unified environment: A selected company case”. The purpose of this survey is to measure both the classic usability aspects and the user experience aspects of the mockup, the first version of the design artifact, using your experiences and feedback to enable a continuous improvement process and design a final solution concept afterward. For the testing, you will be provided with instructions and a link to the dashboard. The survey will be included in the work in an anonymous form and all data will be kept confidential and used only for the purposes of the master thesis, to evaluate and improve the quality of the dashboard.

Introduction to the underlying business problem

BI tools make it possible to identify patterns and trends in data and extract important information that enables companies to accelerate and improve decision-making processes. However, there is often a gap between the information management needs for early detection and proper decision-making. When departments are not provided with flexible and simple tools, they often tend to develop their own reporting solutions. And tools without the support and approval of the IT department often lead to heterogeneous BI system landscapes with multiple non-integrated data sources in which the data is stored independently of each other and possibly even redundantly, which results in high costs for care and maintenance. And even if the data basis is the same, there are sometimes different business logic in the frontend reports that lead to different results and are therefore untransparent.

This is where combining multiple BI tools into an integrated dashboard can help maintain preferences when selecting such software and help all members of an organization move from isolated and project-oriented data use to a fully data-driven culture that provides the foundation for adequate strategic decision-making.

The purpose of this work is to provide a set of guidelines to companies considering merging different BI software to ensure successful integration into a unified BI environment as a basis for strategic decisions. Given the purpose, the goal of this master thesis is to develop a cascading dashboard concept based on SAC and Tableau and to evaluate its feasibility and acceptance.

Please use the link to the Dashboard to explore the dashboard for 10-15 minutes in order to be able to complete the following questionnaire. Always keep the business problem in mind.

https://mhp-management-und-it.eu10.hcs.cloud.sap/sap/fpa/ui/tenants/201d4/bo/application/2A69A82EDC3424DAC4A9BDA17E6237C?mode=present

If you have any questions about the survey, please do not hesitate to contact me.

Please make your evaluation now.

For the assessment of the dashboard, please fill out the following questionnaire. The questionnaire consists of pairs of contrasting attributes that may apply to the dashboard. The circles between the attributes represent gradations between the opposites. You can express your agreement with the attributes by ticking the circle that most closely reflects your impression.

Example:

attractive	□	X	□	□	□	□	□	unattractive

This response would mean that you rate the dashboard as more attractive than unattractive.

Please decide spontaneously. Don’t think too long about your decision to make sure that you convey your original impression.

Sometimes you may not be completely sure about your agreement with a particular attribute, or you may find that the attribute does not apply completely to the particular dashboard. Nevertheless, please tick a circle in every line.

It is your personal opinion that counts. Please remember there is no wrong or right answer!

Please assess the dashboard now by ticking one circle per line.

	1	2	3	4	5	6	7		
annoying	□	□	□	□	□	□	□	enjoyable	1
not understandable	□	□	□	□	□	□	□	understandable	2
creative	□	□	□	□	□	□	□	dull	3
easy to learn	□	□	□	□	□	□	□	difficult to learn	4
valuable	□	□	□	□	□	□	□	inferior	5
boring	□	□	□	□	□	□	□	exciting	6
not interesting	□	□	□	□	□	□	□	interesting	7
unpredictable	□	□	□	□	□	□	□	predictable	8
fast	□	□	□	□	□	□	□	slow	9
inventive	□	□	□	□	□	□	□	conventional	10
obstructive	□	□	□	□	□	□	□	supportive	11
good	□	□	□	□	□	□	□	bad	12
complicated	□	□	□	□	□	□	□	easy	13
unlikable	□	□	□	□	□	□	□	pleasing	14
usual	□	□	□	□	□	□	□	leading-edge	15
unpleasant	□	□	□	□	□	□	□	pleasant	16
secure	□	□	□	□	□	□	□	not secure	17
motivating	□	□	□	□	□	□	□	demotivating	18
meets expectations	□	□	□	□	□	□	□	does not meet expectations	19
inefficient	□	□	□	□	□	□	□	efficient	20
clear	□	□	□	□	□	□	□	confusing	21
impractical	□	□	□	□	□	□	□	practical	22
organized	□	□	□	□	□	□	□	cluttered	23
attractive	□	□	□	□	□	□	□	unattractive	24
friendly	□	□	□	□	□	□	□	unfriendly	25
conservative	□	□	□	□	□	□	□	innovative	26

Please rate the dashboard first before moving to the next page.

Further comments and feedbacks / Suggestions for improvement

If you have further comments regarding Attractiveness* you can express them here:

- –
- –

If you have further comments regarding Efficiency* you can express them here:

- –
- –

If you have further comments regarding Perspicuity* you can express them here:

- –
- –

If you have further comments regarding Dependability* you can express them here:

- –
- –

If you have further comments regarding Stimulation* you can express them here:

- –
- –

If you have further comments regarding Novelty* you can express them here:

- –
- –

If you have any other suggestions for improvement, you can express them here:

- –
- –

Attractiveness*: annoying / enjoyable; bad / good; unlikable / pleasing; unpleasant / pleasant; unattractive / attractive; unfriendly / friendly (Overall impression of the dashboard. Do users like or dislike the dashboard?)

Efficiency*: slow / fast; inefficient / efficient; impractical / practical; cluttered / organized (Can users solve their tasks without unnecessary effort?)

Perspicuity*: not understandable / understandable; difficult to learn / easy to learn; complicated / easy; confusing / clear (Is it easy to get familiar with the dashboard? Is it easy to learn how to use the dashboard?)

Dependability*: unpredictable/ predictable; obstructive/ supportive; not secure / secure; does not meet expectations / meets expectations (Does the user feel in control of the interaction?)

Stimulation*: inferior / valuable; boring / exciting; not interesting / interesting; demotivating / motivating (Is it exciting and motivating to use the dashboard?)

Novelty*: dull / creative; conventional / inventive; usual/ leading edge; conservative / innovative (Is the dashboard innovative and creative? Does the dashboard catch the interest of users?)

Appendix 3: Interview questions

Q1 What is your current position in the company?

Q2 How many years have you worked in this position and how many years have you been in the industry?

Q3 Can you describe what kind of information you use regularly in your work?

Q4 How often do you work with this information and how important is the analysis of this information for your work?

Q5 Do you have information in different reports today that you want to analyze/visualize in the same dashboard?

Q6 Which BI tools do you already have experience with, or which tools do you use in your company? Do you think that using the preferred software tools would improve your work performance and increase your productivity?

Q7 If you were to use the integrated cascading dashboard in your work, would you find it useful and could you complete your tasks faster compared to the existing dashboards? In your opinion, what are the advantages and disadvantages of the new solution concept?

Q8 Would you find the integrated dashboard flexible compared to the previous dashboards? In what ways can the dashboard create (more) flexibility?

Q9 Would you find the dashboard in this form easy to use compared to previous dashboards? Which dashboard features are particularly user-friendly?

Q10 Would this dashboard concept help you in your decision-making? For what reason and in what way?

Q11 Do you think this concept can support decision-makers at all levels (vertical axis)? Where do you think the concept can be applied?

Q12 Have you used similar dashboards before? If so, in what form?

Q13 Could you also imagine implementing such a solution concept in your company/department/team?

Q14 Is there anything you would like to add?

Appendix 4: Data set overview - Data Preparation Phase

costs_price_drip_pans

Type	Field name	View
Abc	name	DP-150, DP-150 light, DP-220, …
Abc	price (€)	0,5, 0,4, 0,7, …
Abc	costs (€)	0,45, 0,35, 0,6, …

costs_price_metal_covers

Type	Field name	View
Abc	name	BeyondCover 265, BeyondCover 345, MC-115 light, …
Abc	price (€)	55, 65, 6,5, …
Abc	costs (€)	50, 55, 6, …

customers_drip_pans

Type	Field name	View
#	ID	0, 1, 2, …
Abc	Name	Madness Automotive SE, Roony's Ersatzteile GmbH, …
Abc	Location	Distelstraße 19, 71636, Ludwigsburg, Deutschland, …
Abc	Responsible	Heiko Hafele, Rooney Räuber, …
Abc	E-Mail	heiko.Hafele@madness.com, rooney.räuber@rooney.com, …
#	Tel.- Nr.	1520598498, 1535818598, …
#	Anzahl	23, 45, 40, …

orders_drip_pans

Type	Field name	View
Abc	Order ID	A-DP-150 light-10, A-DP-150 light-104, …
Abc	Product	DP-150 light
#	Customer ID	5, 7, 3, …
Abc	Customer	Horiba AG, Becker GmbH, …
#	Qunatity	1.350.000, 2.000.000, …
Date	Order Entry	30.03.2021, …

geocoordinates

Type	Field name	View
Abc	Location	Ulm, Hamburg, ...
Abc	Longitude	9.95174569599638, ...
Abc	Latidute	48.39998978845912, ...

punching_machines

Type	Field name	View
Abc	machine_id	S-8170, S-6315, S-3815, …
Abc	machine_information. Type of Machine	Stanzzentrum, Feinstanzpresse, …
Abc	machine_information. Type	Holecut FlexPunch, HRS320, HFA 320, …
Abc	machine_information. Manufacturer	EHRT, SCHMID, FEINTOOL, …
#	machine_information. Stroke Rate	120, 80, …
#	machine_information. Total Force	120, 250, 320, …
Abc	location.Country	Germany, …
Abc	location.Plant Location	Ulm, …
Abc	location.Building	UL-PM, …
Abc	location.Position	1PO, 1P1, 1P2, …

powder_coating_machines

Type	Field name	View
Abc	machine_id	P0-0001, P0-0002, …
Abc	machine_information. Type of Machine	Pulverbeschichtungsanlage, …
Abc	machine_information. Type	Pulverbeschichtungsanlage mit Kreisförderanlage, …
Abc	machine_information. Manufacturer	EHRT, SCHMID, FEINTOOL, …
#	machine_information. Flow.Rate (pcs/h)	52, …
Abc	location.Country	Germany, …
Abc	location.Plant Location	Ulm, …
Abc	location.Building	UL-PM, HH-LCM, …
Abc	location.Position	1PO, 1P1, 1P2, …

laser_cutting_machines

Type	Field name	View
Abc	machine_id	L-7493, L-7262, L-9489, …
Abc	machine_information. Type of Machine	Leaserbearbeitungszentum, …
Abc	machine_information. Type	skyCUBE SLclass, …
Abc	machine_information. Manufacturer	PFEIFER, TRUMPF
Abc	machine_information. Workspace [mm]	1250 x 2450 x 30 mm, …
Abc	location.Country	Germany, …
Abc	location.Plant Location	Ulm, …
Abc	location.Building	UL-LCM, …
Abc	location.Position	1LO, 1L1, 1L2, …

orderdata_punchingmachine

Type	Field name	View
Abc	Auftragsnummer	A-DP-150-1, …
Abc	Produkt	DP-150, …
#	Tagesmenge	54.872, 55.382, …
#	Ausschussteile	1, 2, 12, …
Date	Timestamp	02.01.2020, …

orderdata_lasercuttingmachines

Type	Field name	View
Abc	Auftragsnummer	A-MC-BC-265, …
Abc	Produkt	BeyondCover 265, …
#	Ist-Tagesmenge	500, …
#	Soll-Tagesmenge	600, …
Abc	Maschine	L-1576, …
Date	Timestamp	07.01.2020, …

orderdata_powdercoatingmachine_punchingmachine

Type	Field name	View
Date	Datum	02.01.2020, …
Abc	Auftragsnummer	A-MC-BC-345, A-MC-BC-265, …
Abc	Produkt	MC-115 light, BeyondCover 345, …
#	Tagesmenge	362, 430, …
Abc	Maschine	PO-0001, …

products_drip_pans

Type	Field name	View
Abc	_id	6224c2e6442ef86a1412d30c, 6224c893442ef86a1412d30f, …
Abc	name	DP-220 solid, DriPa Automotive 85, …
Abc	material	HC260Y, HC420LA, …
Abc	dimnesions (mm)	220x40x10, 85x30x5, …
#	weight (kg)	0.220, 0.055, …

products_metal_covers

Type	Field name	View
Abc	_id	626a3804b40a3e7c729e69a5, 626a396cb40a3e7c729e69a7, ...
Abc	name	BeyondCover 265, MC-115 light, ...
Abc	material	S275N, S275M, ...
Abc	dimnesions (mm)	350x150x10, 115x80x5, ...
#	weight (kg)	4.121, 0.361, ...

machinecard_powdercoatingmachine

Type	Field name	View
Date	Datum	02.01.2022, …
Abc	Maschine	PO-0001, …
#	Ruhezeit	0,35, 0,4, 0,45, …
#	Farbwechselzeit	0,6 0,2, 0,45, …
#	Laufzeit	9,05, 9,4, 9,1, …
Abc	Auftrag	A-MC-BC-345, …
Abc	Notiz	Accent orange [RAL0606080], …

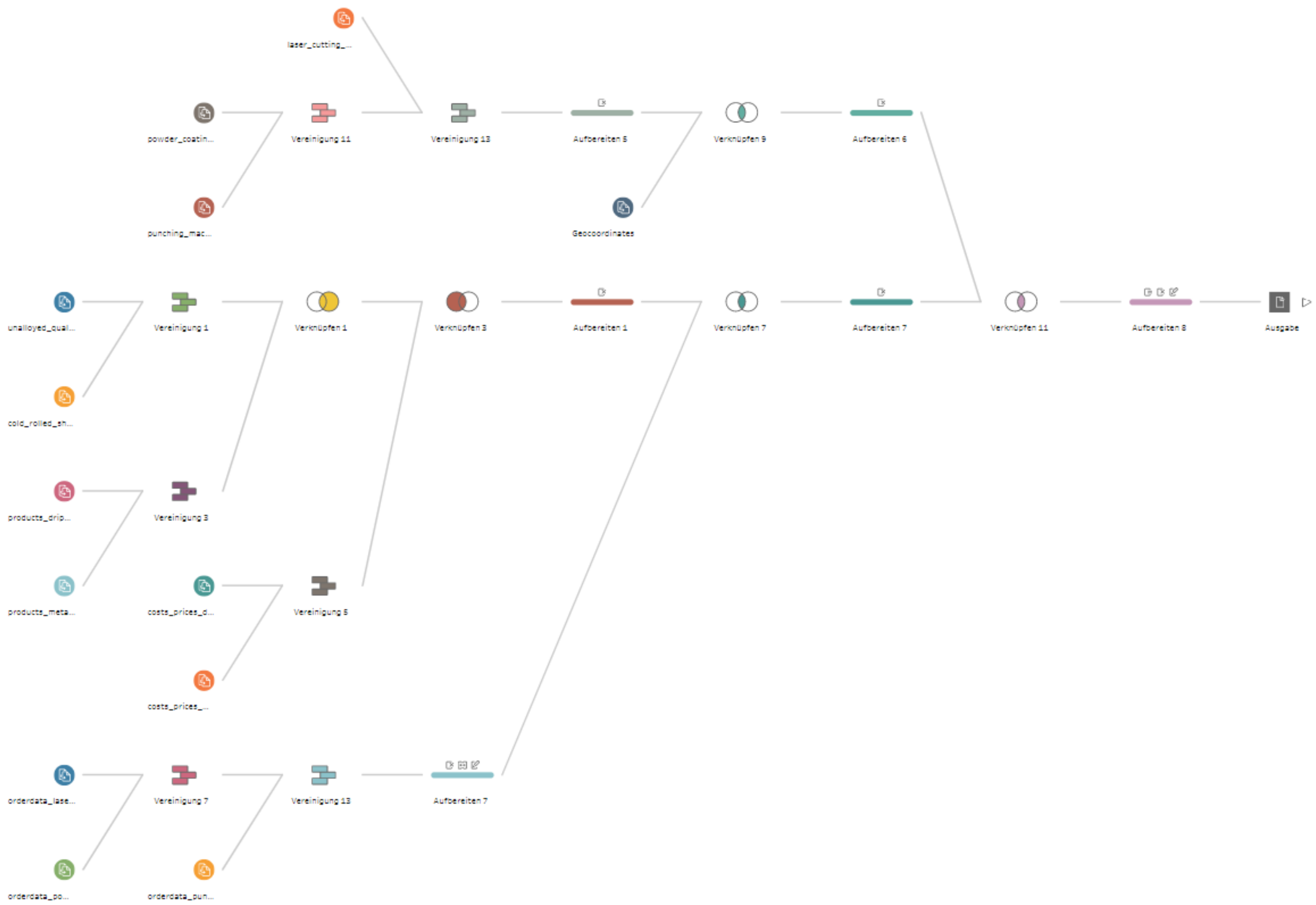
unalloyed_quality_steel

Type	Field name	View
Abc	Kurzname	S275N, S275M, S355N, …
#	Werkstoffnummer	1,049, 1,8818, 1,0545, …
#	Zugfestigkeit [N/mm^2]	420, 425, 520, …
#	Streckgrenze [N/mm^2]	265, 345, …
#	Bruchdehnung [%]	22, 24, …

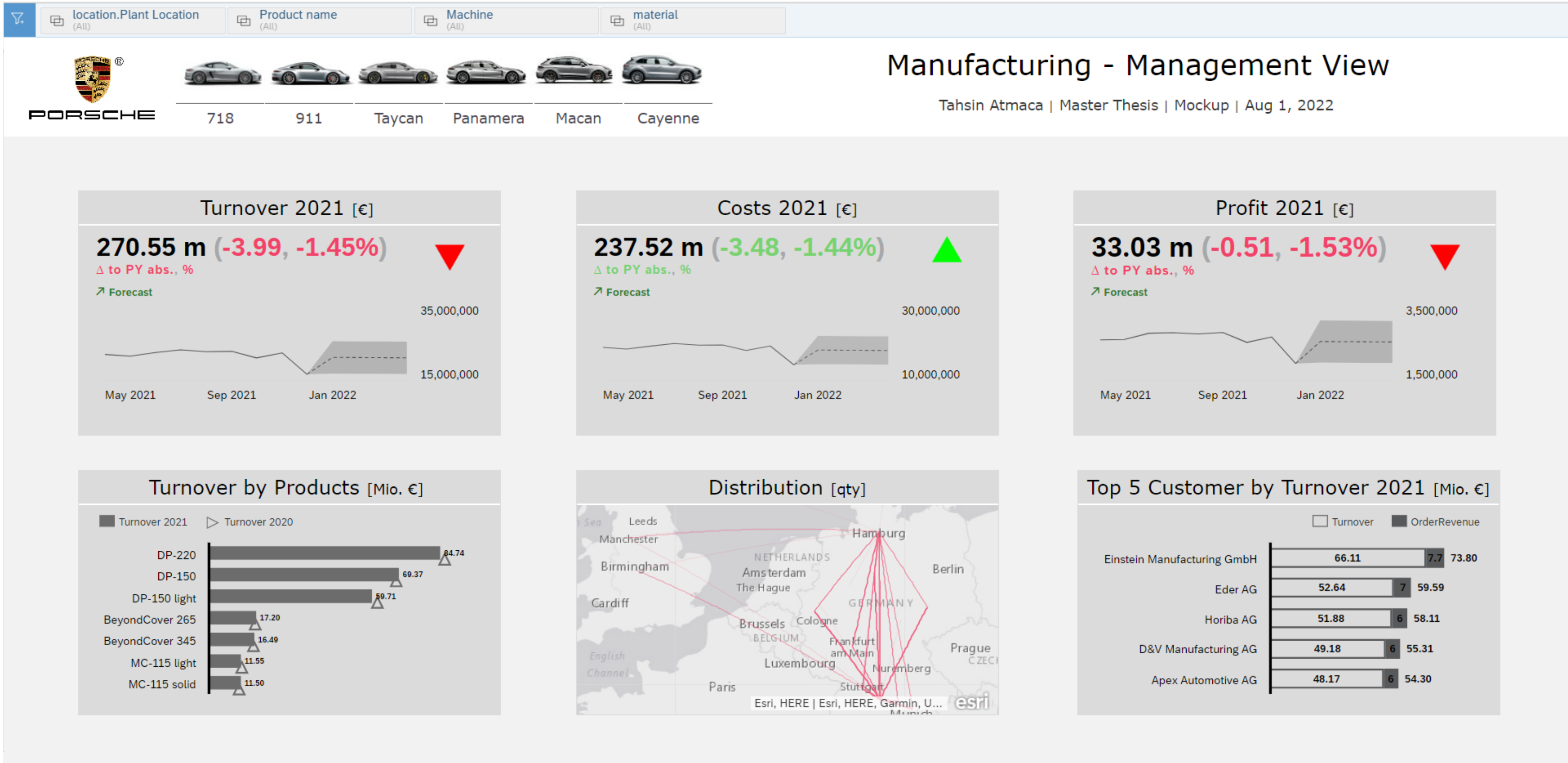
cold_rolled_sheet_metal

Type	Field name	View
Abc	Kurzname	HC180Y, HC260Y, HC300P, …
#	Werkstoffnummer	1,0922, 1,0928, 1,0448, …
#	Zugfestigkeit [N/mm^2]	340, 440, 400, …
#	Streckgrenze [N/mm^2]	180, 320, 300, …
#	Bruchdehnung [%]	36, 32, 26, …

Appendix 5: Data preparation scheme - Data Preparation Phase



Appendix 6: Mockup Screenshot “Manufacturing – Management View”



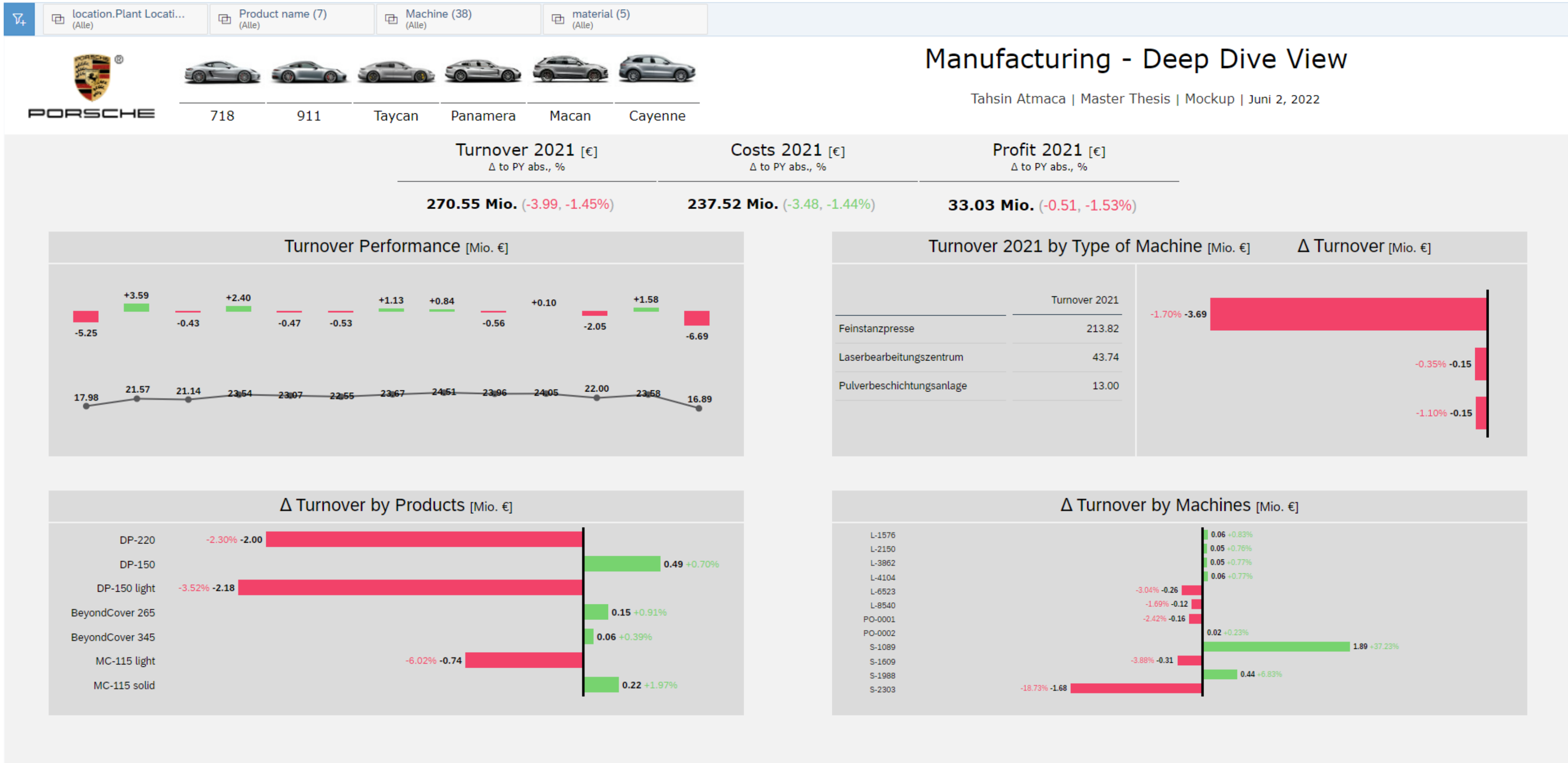
Appendix 7: R Visualizations Script

```
x<-c(1)
data1<-Datamodel_Showcase_Manufacturing$`Turnover 2021`
plot(x,xaxt='n',yaxt='n',
frame.plot=FALSE,ann=FALSE,
pch=ifelse(data1>=Datamodel_Showcase_Manufacturing$`Turnover 2020`,24,25),cex=25,
col=ifelse(data1>=Datamodel_Showcase_Manufacturing$`Turnover 2020`,"green","red"),
bg=ifelse(data1>=Datamodel_Showcase_Manufacturing$`Turnover 2020`,"green","red"),lwd=1)
```

```
x<-c(1)
data1<-Datamodel_Showcase_Manufacturing$`Costs 2020`
plot(x,xaxt='n',yaxt='n',
frame.plot=FALSE,ann=FALSE,
pch=ifelse(data1>=Datamodel_Showcase_Manufacturing$`Costs 2021`,24,25),cex=25,
col=ifelse(data1>=Datamodel_Showcase_Manufacturing$`Costs 2021`,"green","red"),
bg=ifelse(data1>=Datamodel_Showcase_Manufacturing$`Costs 2021`,"green","red"),lwd=1)
```

```
x<-c(1)
data1<-Datamodel_Showcase_Manufacturing$`Profit 2021`
plot(x,xaxt='n',yaxt='n',
frame.plot=FALSE,ann=FALSE,
pch=ifelse(data1>=Datamodel_Showcase_Manufacturing$`Profit 2020`,24,25),cex=25,
col=ifelse(data1>=Datamodel_Showcase_Manufacturing$`Profit 2020`,"green","red"),
bg=ifelse(data1>=Datamodel_Showcase_Manufacturing$`Profit 2020`,"green","red"),lwd=1)
```

Appendix 8: Mockup Screenshot “Manufacturing – Deep Dive View” (SAC)



Appendix 9: Mockup Screenshot “Manufacturing – Deep Dive View” (Tableau)

Plant Loc... (Alle) | Product n... (Alle) | Machine (Alle) | material (Alle)

PORSCHE

718 | 911 | Taycan | Panamera | Macan | Cayenne

Manufacturing - Deep Dive View

Tahsin Atmaca | Master Thesis | Mockup | Juni 2, 2022

Turnover 2021 [€] Δ to PY abs., %	Costs 2021 [€] Δ to PY abs., %	Profit 2021 [€] Δ to PY abs., %
270,58M -3,96M -1,44%	237,54M -3,46M -1,43%	33,03M -0,51M -1,52%

Machine Overview

Machine	Type of Machine	Manufacturer	Type	Country	Plant Location	Building	Position	Turnover 2021	
L-1576	Laserbearbeitungszentrum	TRUMPF	TruLaser 3030	Germany	Ulm	UL-LCM	1L19	7,18M	0,83%
L-2150	Laserbearbeitungszentrum	TRUMPF	TruLaser 3030	Germany	Hamburg	HH-LCM	1L16	6,81M	1,14%
L-3862	Laserbearbeitungszentrum	TRUMPF	TruLaser 3030	Germany	Ulm	UL-LCM	1L18	6,79M	0,77%
L-4104	Laserbearbeitungszentrum	TRUMPF	TruLaser 3030	Germany	Hamburg	HH-LCM	1L17	7,83M	0,77%
L-6523	Laserbearbeitungszentrum	PFEIFER	skyCUBE Pclass	Germany	Hamburg	HH-LCM	1L15	8,16M	-3,04%
L-8540	Laserbearbeitungszentrum	PFEIFER	skyCUBE Pclass	Germany	Ulm	UL-LCM	1L6	7,00M	-1,69%
PO-0001	Pulverbeschichtungsanlage	Durst GmbH	Pulverbeschichtungsanlage mit Kreisförderanlage	Germany	Ulm	UL-LCM	0P0	6,46M	-2,42%
PO-0002	Pulverbeschichtungsanlage	SIEGERT GmbH	Pulverbeschichtungsanlage mit Kreisförderanlage	Germany	Hamburg	HH-LCM	1P0	6,54M	0,23%
S-1089	Feinstanzpresse	FEINTOOL	HFA 320	Germany	Ulm	UL-PM	1P19	6,96M	37,23%
S-1609	Feinstanzpresse	FEINTOOL	HFA 320	Germany	Ulm	UL-PM	1P16	7,63M	-3,88%
S-1988	Feinstanzpresse	FEINTOOL	HFA 320	Germany	Ulm	UL-PM	1P10	6,91M	6,83%
S-2303	Feinstanzpresse	FEINTOOL	HFA 320	Germany	Ulm	UL-PM	1P20	7,29M	-18,73%

Laser Cutting Machines (Logfiles)

Machine	Date	Type	Code	Code Description	Daily Output	Daily Output (Target)	Status	
	09.06.2021	skyCUBE Pclass	P-042	Access to the network denied	0	5.000	Error	6.000
	30.09.2021	skyCUBE Pclass	P-156	Routine cleaning of the mirrors	5.000	5.000	Warning	
	11.10.2021	skyCUBE Pclass	P-156	Low oil pressure	5.000	5.000	Warning	
L-8540	24.04.2020	skyCUBE Pclass	P-115	Refill cooling water	500	500	Warning	
	08.05.2020	skyCUBE Pclass	P-156	Low oil pressure	500	500	Warning	
	15.12.2020	skyCUBE Pclass	P-215	Routine cleaning of the mirrors	500	500	Warning	
	04.01.2021	skyCUBE Pclass	P-157	Oil pressure too low - operation not possible	0	500	Error	1.440
	15.03.2021	skyCUBE Pclass	P-156	Low oil pressure	1.000	1.000	Warning	
	19.03.2021	skyCUBE Pclass	P-115	Refill cooling water	500	500	Warning	
	24.05.2021	skyCUBE Pclass	P-215	Routine cleaning of the mirrors	500	500	Warning	
	28.05.2021	skyCUBE Pclass	P-156	Low oil pressure	500	500	Warning	
	21.06.2021	skyCUBE Pclass	P-156	Low oil pressure	500	500	Warning	

Appendix 10: SAP Analytics Cloud URL API Filter Parameters

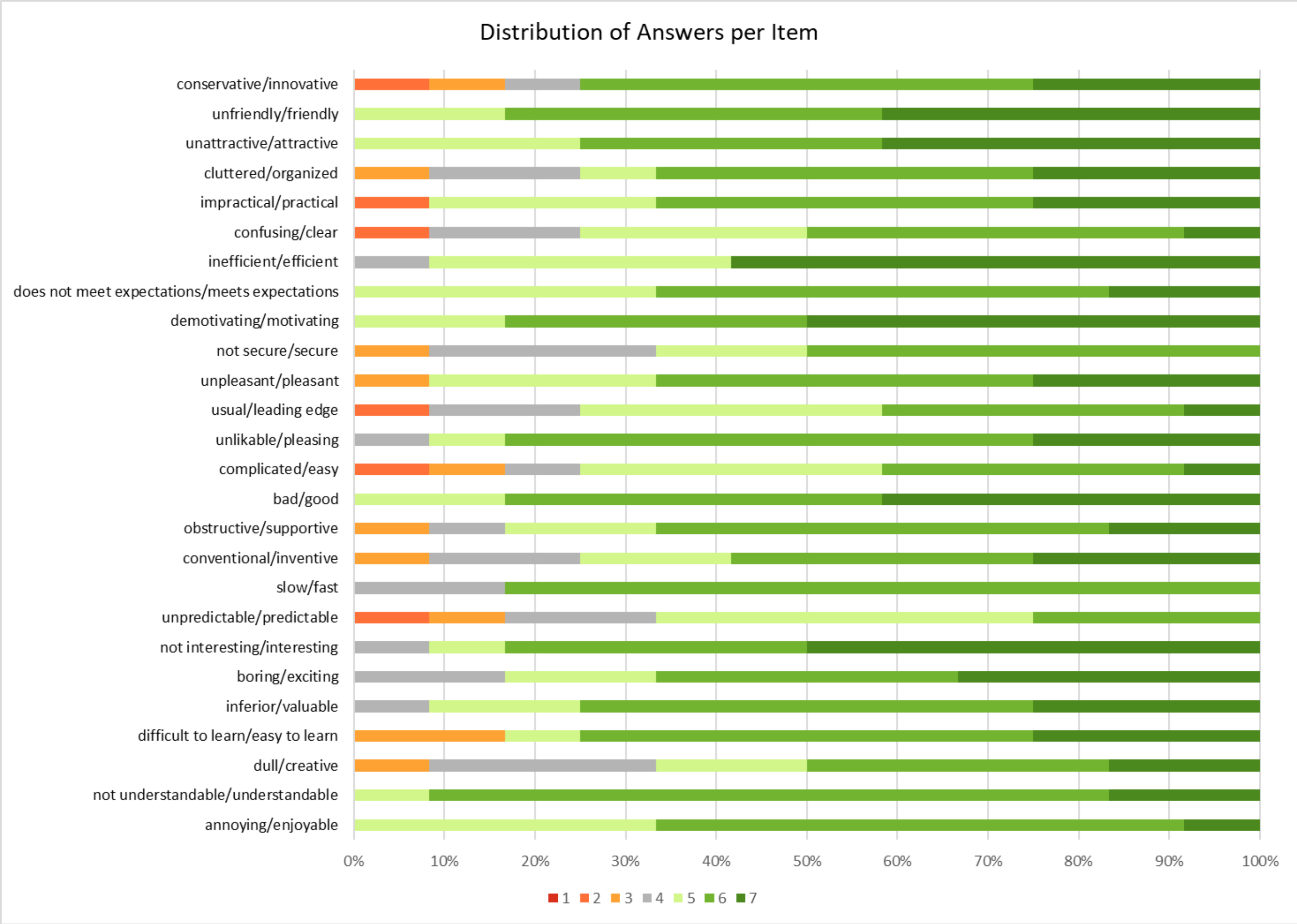
```
// Dimension filter _ location.Plant Location
var location = InputControl_1.getInputControlDataSource().getActiveSelectedMembers();

var location_filtervalues = "%5B%22";

for (var a = 0; a<location.length; a++) {
    if (a === (location.length - 1)){
        location_filtervalues = location_filtervalues + location[a].id + "%22%5D";
    } else {
        location_filtervalues = location_filtervalues + location[a].id + "%22%2C%22";
    }
}

NavigationUtils.openStory("84A01787CCB1491499939F84A992D835", "199780ac-b73e-40f9-be8e-e64f24e72ada",
    [UrlParameter.create("mode", "present"),
    UrlParameter.create("f01Model","t.X.CB3V78P29LFYWU9QPWS1E9PPTS:CB3V78P29LFYWU9QPWS1E9PPTS"),
    UrlParameter.create("f01Dim","locationPlant_Location"),
    UrlParameter.create("f01Val",location_filtervalues)],
                          true);
```

Appendix 11: SAP Analytics Cloud Hyperlink Filter Parameters

URL:
https://dub01.online.tableau.com/#/site/tableaumhp/views/third_level/Dashboard1?:embed=yes&:toolbar=no&Product name="value"

URL encoded:
https://dub01.online.tableau.com/#/site/tableaumhp/views/third_level/Dashboard1?%3Aembed=yes&%3Atoolbar=no&Product%20name="value"

Appendix 12: Distribution of survey answers per item



Appendix 13: Feedback from internal survey

Master Thesis - Tahsin Atmaca
User Experience Questionnaire (UEQ) - Feedback

Attractiveness

User 1	"One landing page with process and business story might make it more attractive."
User 3	"Very innovative, eager to see the final result."
User 4	"Pictures suggest that user can filter by carline."
User 5	"Turnover by Products: Maybe two bars per product would be a little better to read the chart directly."
User 5	"Turnover by Products: In addition, deviations to the previous year would be advantageous to quickly see how the sales of the products are developing."
User 5	"Deep Dive: Probably it would look better if the KPIs are above the labels (3 KPIs: Turnover, Costs, and Profit)."
User 6	"Looks good, especially the vehicle models attract attention."
User 7	"Check the font size of all texts and try to arrange them, so that you have less than 4 different sizes (headline, sub-headline, standard). In addition to that maybe highlighting will help as well. Highlights should show just the important stuff."
User 7	"Different red/green color-coding in the different dashboards – can they be aligned?"
User 7	"Spaces (especially free space) between the different apps are different. Flip through the screenshots and see the spaces."
User 8	"Very structured and clear layout design."
User 8	"Good overall coloring and readability."
User 9	"The selection of different visualization options guides the user through the dashboard."
User 9	"The user can quickly find the desired content."
User 10	"I like the use of signal colors only. They have a meaning. It takes the focus on the important things."
User 11	"Minimalistic but full of information."
User 11	"Clean interface that is responsive."

Efficiency

User 4	"Filters are not clear, only technical descriptions."
User 4	"The data date is not clear!"
User 5	"It may make sense to jump directly from the "Turnover by Products" and "Top 5 Customers by Turnover" charts. The way to filter first and then jump off is not quite intuitive. (table continues)

	Maybe both functions (navigation to deep dive and filter) can be implemented on these charts.”
User 5	“Forecasts are relatively intensive if it comes to performance. Maybe it would be better to find the forecasts in deep dives rather than directly on the first management view (even if they look fancy).”
User 6	“The diagrams are self-explanatory.”
User 8	“Integrated filter options make it easy for the end-user to handle the dashboard and conduct independent analyses.”
User 9	“Depending on the user group, practical and quick overview of necessary KPIs (structured presentation of KPIs in three levels).”

Perspicuity

User 2	“Sometimes it is a bit hard to understand what the data wants to say, a bit more information would be great (e.g., downtime in Tableau), mouseover is not always the best way.”
User 3	“Understanding and both BI tools well connected.”
User 4	“Geomap does not provide additional information.”
User 5	“I've already noted it on Efficiency - I think it would be somewhat easy if you could place the jumps on the charts. Or it would have to be clearer where I can jump off.”
User 6	“Clicking on the diagrams is a bit confusing.”
User 7	“Top 5 Customers by Turnover” – what’s the percentage of these Top 5 Customers? What is the rest? (Maybe another bar called “rest” would enhance the perspicuity of this specific key figure.”
User 8	“Easy and understandable navigation through the dashboards via data-story telling approach.”
User 9	“Navigation is not directly apparent to the user.”
User 9	“The user could be better guided through the dashboard (by icons, legends, comments).”
User 10	“It is easy to get familiar with it.”

Dependability

User 4	“It is not clear at first glance that there are predictions in the timeline graphs.”
User 5	“I think it's hard to test because it would only show up after GoLive if some real users would access it.”
User 7	“On pages 1 and 2 – Costs are -3,48Mio; on Page 3 the Costs are - 3,46 Mio € - where comes the difference from?”
User 7	“Turnover 2021 by Type of machine: What does the bar show? What’s the comparison? I just see -1,7ß% - but compared to what? Previous year? Plan value?”
User 8	“Through structured design and clear navigation paths, the end-user feels very comfortable interacting with the dashboard and navigating through it.”

Stimulation

User 5	“The dashboards are nice to look at and their interactions make you want more.”
User 8	“Through various interactions within and across the different diagrams the end-user is motivated to further interact with the dashboard and get an even better understanding of the data.”
User 9	“Dashboard adds value by compactly presenting KPIs and linking multiple BI tools.”
User 10	“It is exciting to use the dashboard, because of interaction it is likely to play with the data.”

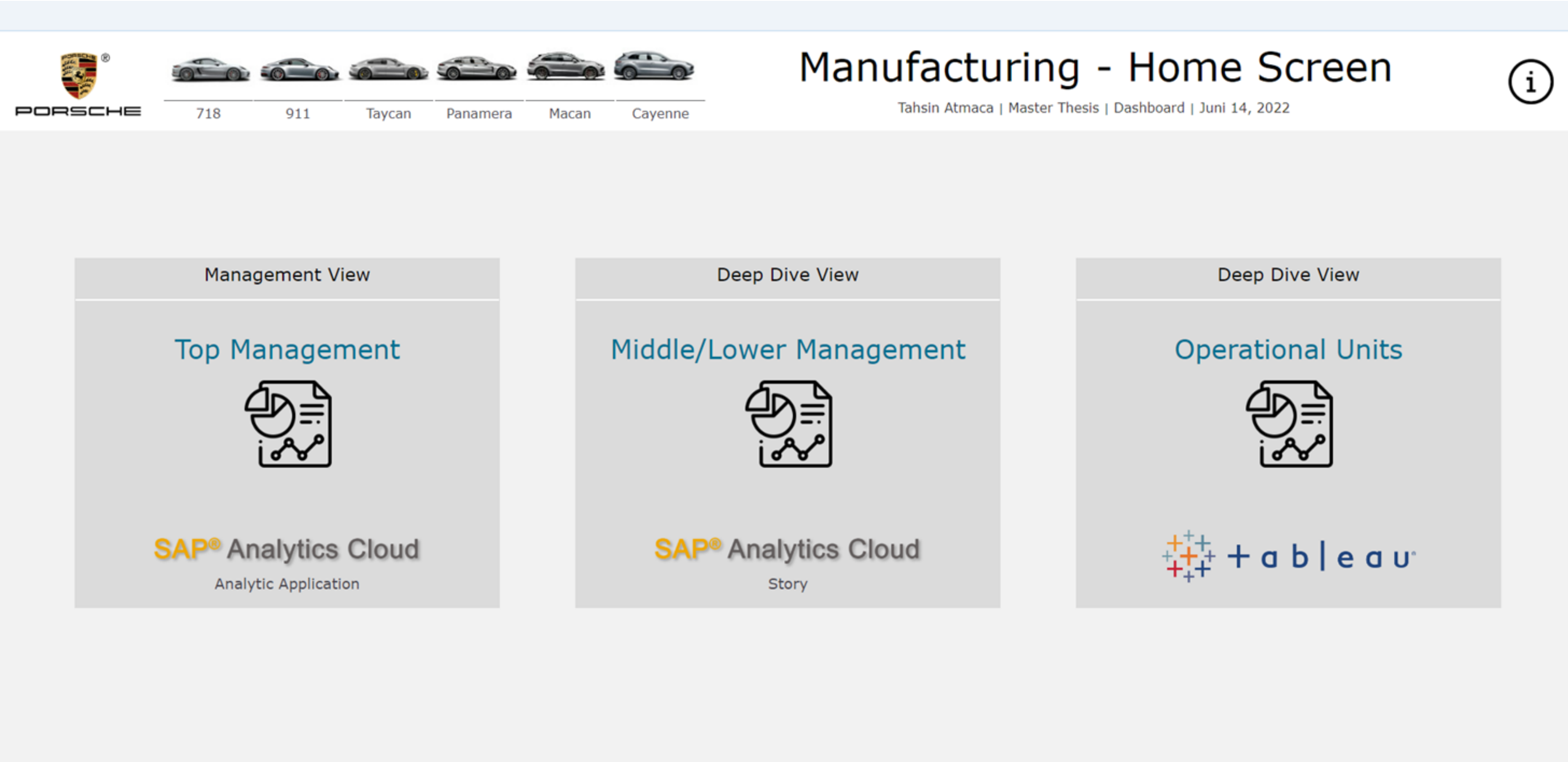
Novelty

User 5	“By jumping across multiple systems, I think the reporting meets the needs of the departments exactly. This should be pursued further.”
User 8	“See comments on stimulation – same applies to novelty and the end user’s sparked interest.”
User 9	“Selecting the display options directs the user to proceed with the dashboard.”
User 10	“I like the deltas. It directly catches the interest of the user. Why was my turnover less than last year? How did I improve my cost rate? And so on.”

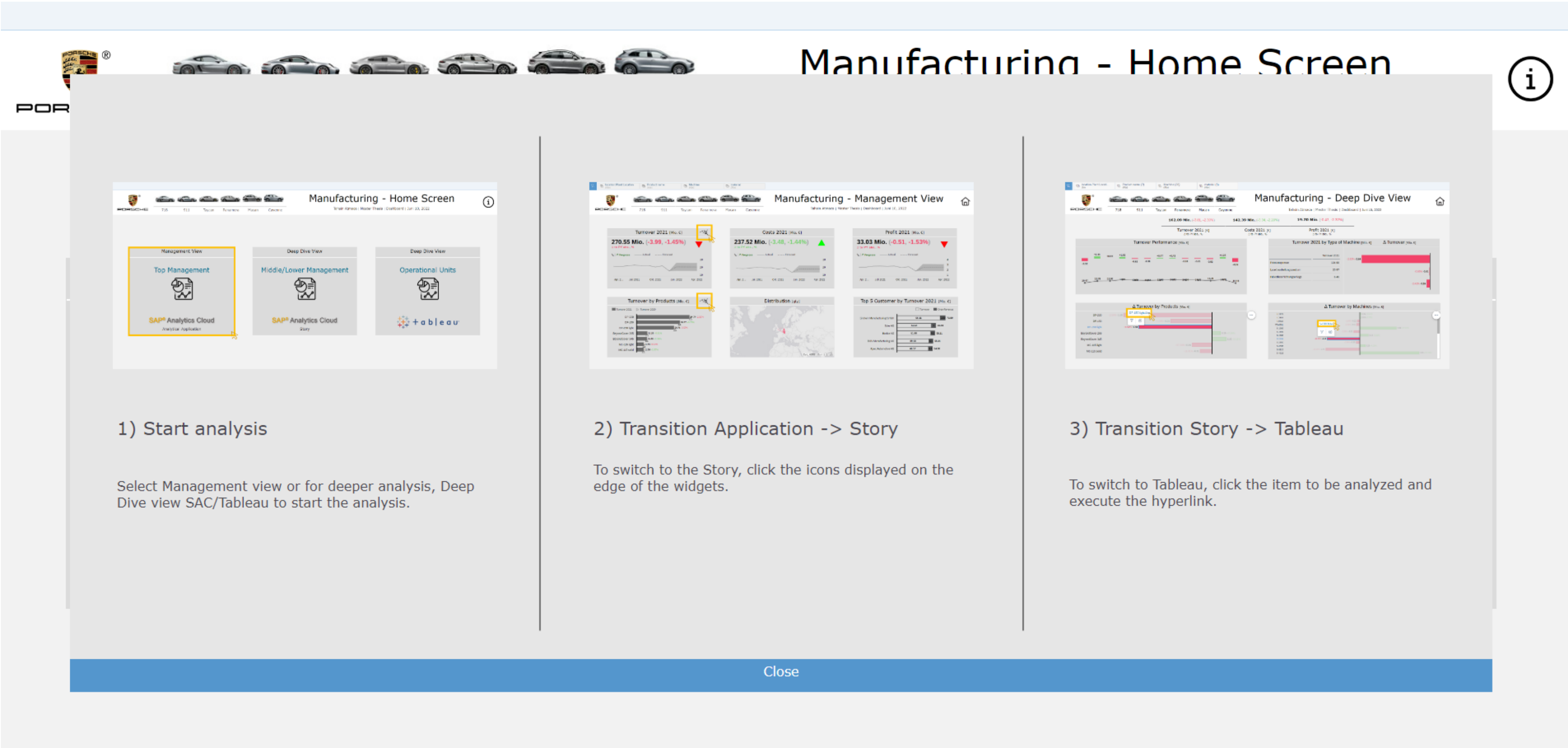
Further comments

User 7	“Scaling of the Top charts of the first Dashboard. The lower Key figures are “in Million”, the KPI-Tile of the Top Chart is also “ in Million”, but the chart itself is in € (even though the values are in Million).”
User 8	“Management View – Top 5 Customer by Turnover maybe change the font color of “Order Revenue” to white. Currently, the numbers are quite hard to read.”
User 8	“Deep Dive View – Turnover 2021 by Type of Machine & Delta Turnover maybe adjust the headers to the table and/or diagram below.”
User 8	“Both pages – Turnover 2021, Costs 2021 and Profit 2021 also Mio. € as a unit.”
User 9	“Legend for navigation and used colors or objects (Info button).”
User 9	“Home button for deep-dive views, to get back to the overview.”
User 9	“Formatting data identifier Top 5 Customer.”
User 9	“KPI of sales/profit/costs only in % and not absolute.”
User 9	“Timeline of key performance indicator development can be displayed only for the current quarter (overall view can be expanded in Deep Dive).”

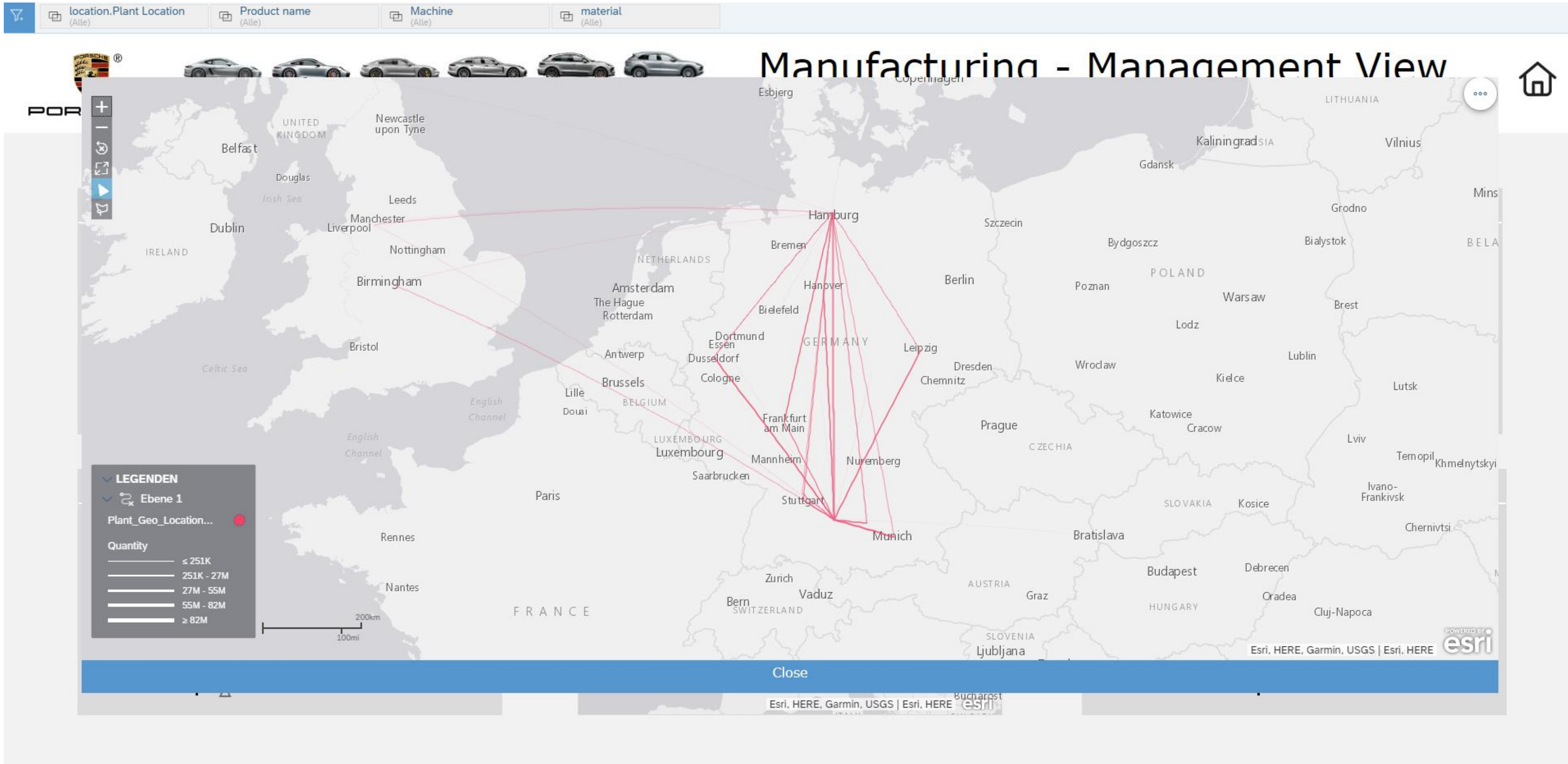
Appendix 14: Dashboard Screenshot "Manufacturing – Home Screen"



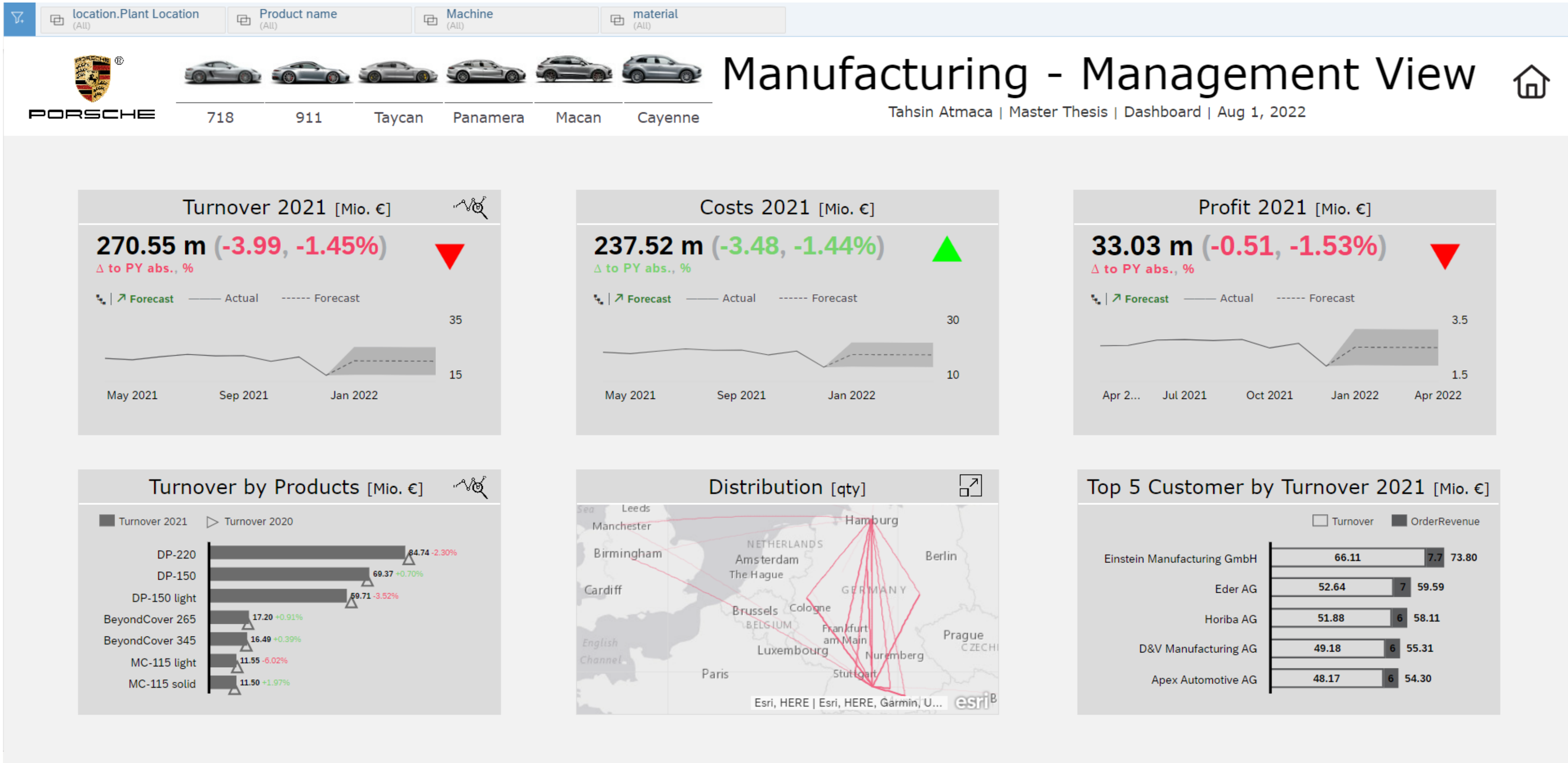
Appendix 15: Dashboard Screenshot Info Panel



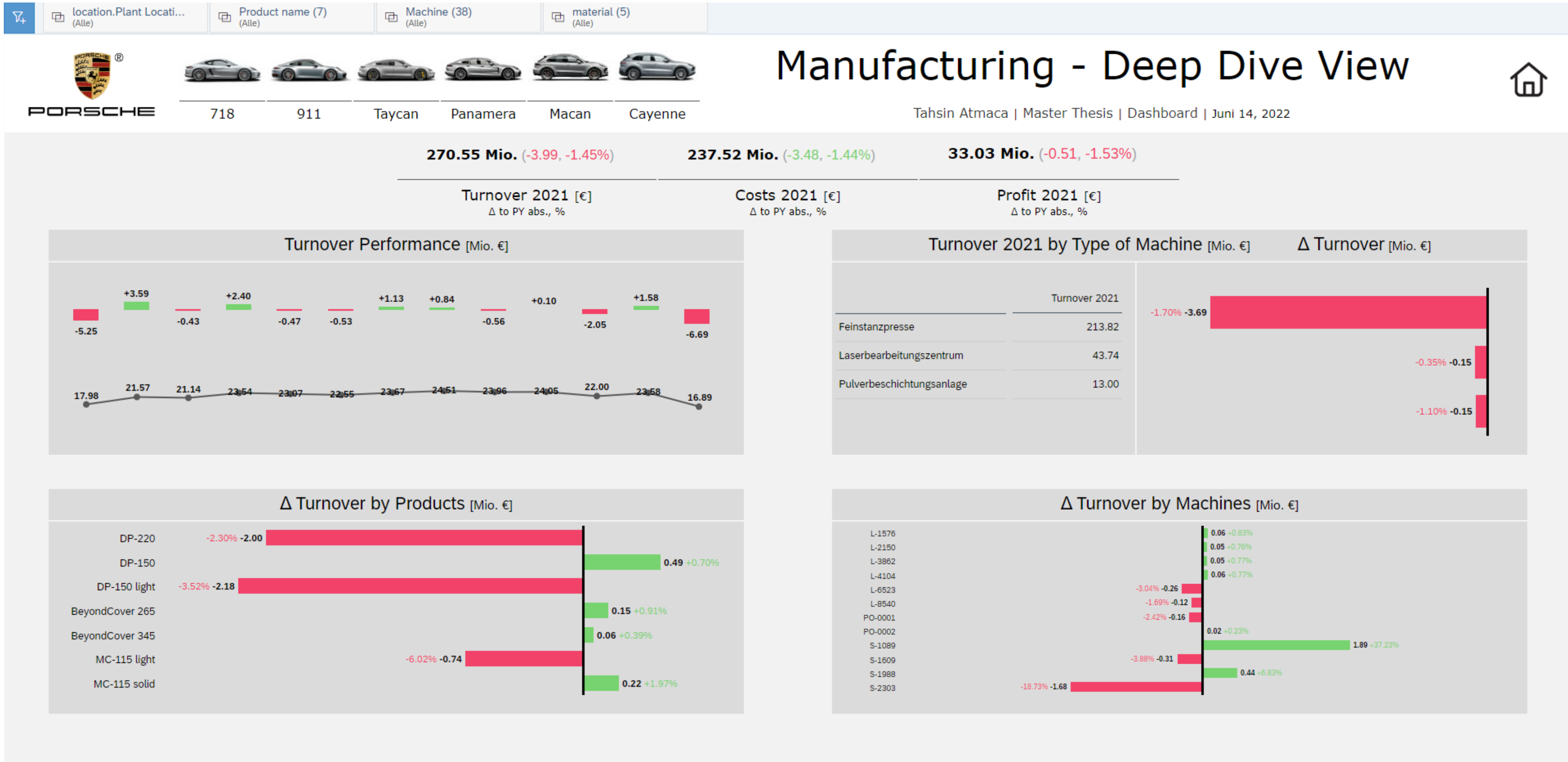
Appendix 16: Dashboard Screenshot Geo-Map Full Screen



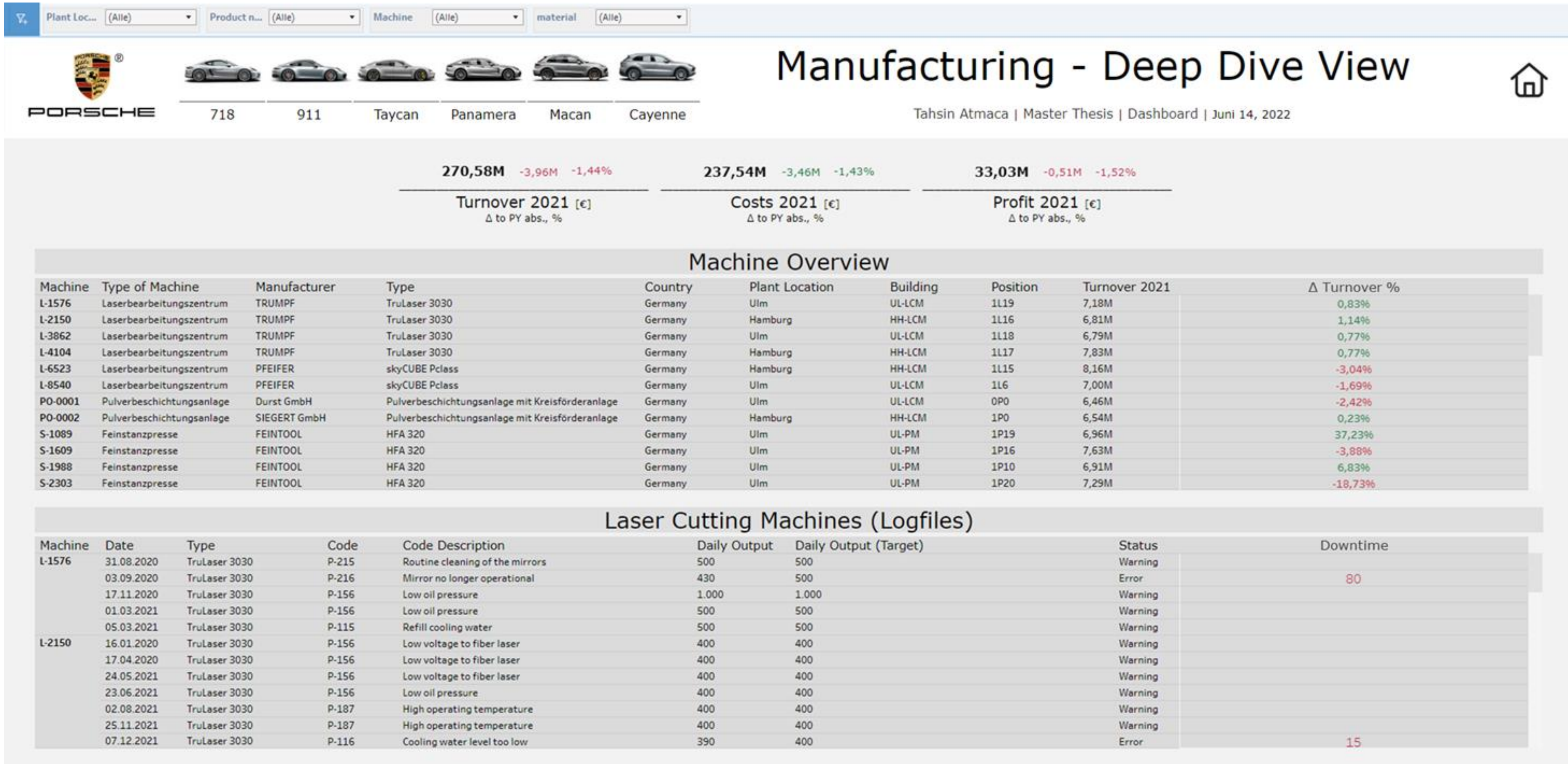
Appendix 17: Dashboard Screenshot "Manufacturing – Management View"



Appendix 18: Dashboard Screenshot “Manufacturing – Deep Dive View” (SAC)



Appendix 19: Dashboard Screenshot “Manufacturing – Deep Dive View” (Tableau)



Machine Overview

Machine	Type of Machine	Manufacturer	Type	Country	Plant Location	Building	Position	Turnover 2021	Δ Turnover %
L-1576	Laserbearbeitungszentrum	TRUMPF	TruLaser 3030	Germany	Ulm	UL-LCM	1L19	7,18M	0,83%
L-2150	Laserbearbeitungszentrum	TRUMPF	TruLaser 3030	Germany	Hamburg	HH-LCM	1L16	6,81M	1,14%
L-3862	Laserbearbeitungszentrum	TRUMPF	TruLaser 3030	Germany	Ulm	UL-LCM	1L18	6,79M	0,77%
L-4104	Laserbearbeitungszentrum	TRUMPF	TruLaser 3030	Germany	Hamburg	HH-LCM	1L17	7,83M	0,77%
L-6523	Laserbearbeitungszentrum	PFEIFER	skyCUBE Pclass	Germany	Hamburg	HH-LCM	1L15	8,16M	-3,04%
L-8540	Laserbearbeitungszentrum	PFEIFER	skyCUBE Pclass	Germany	Ulm	UL-LCM	1L6	7,00M	-1,69%
PO-0001	Pulverbeschichtungsanlage	Durst GmbH	Pulverbeschichtungsanlage mit Kreisförderanlage	Germany	Ulm	UL-LCM	0P0	6,46M	-2,42%
PO-0002	Pulverbeschichtungsanlage	SIEGERT GmbH	Pulverbeschichtungsanlage mit Kreisförderanlage	Germany	Hamburg	HH-LCM	1P0	6,54M	0,23%
S-1089	Feinstanzpresse	FEINTOOL	HFA 320	Germany	Ulm	UL-PM	1P19	6,96M	37,23%
S-1609	Feinstanzpresse	FEINTOOL	HFA 320	Germany	Ulm	UL-PM	1P16	7,63M	-3,88%
S-1988	Feinstanzpresse	FEINTOOL	HFA 320	Germany	Ulm	UL-PM	1P10	6,91M	6,83%
S-2303	Feinstanzpresse	FEINTOOL	HFA 320	Germany	Ulm	UL-PM	1P20	7,29M	-18,73%

Laser Cutting Machines (Logfiles)

Machine	Date	Type	Code	Code Description	Daily Output	Daily Output (Target)	Status	Downtime
L-1576	31.08.2020	TruLaser 3030	P-215	Routine cleaning of the mirrors	500	500	Warning	
	03.09.2020	TruLaser 3030	P-216	Mirror no longer operational	430	500	Error	80
	17.11.2020	TruLaser 3030	P-156	Low oil pressure	1.000	1.000	Warning	
	01.03.2021	TruLaser 3030	P-156	Low oil pressure	500	500	Warning	
	05.03.2021	TruLaser 3030	P-115	Refill cooling water	500	500	Warning	
L-2150	16.01.2020	TruLaser 3030	P-156	Low voltage to fiber laser	400	400	Warning	
	17.04.2020	TruLaser 3030	P-156	Low voltage to fiber laser	400	400	Warning	
	24.05.2021	TruLaser 3030	P-156	Low voltage to fiber laser	400	400	Warning	
	23.06.2021	TruLaser 3030	P-156	Low oil pressure	400	400	Warning	
	02.08.2021	TruLaser 3030	P-187	High operating temperature	400	400	Warning	
	25.11.2021	TruLaser 3030	P-187	High operating temperature	400	400	Warning	
	07.12.2021	TruLaser 3030	P-116	Cooling water level too low	390	400	Error	15

Appendix 20: Interview Protocol Business User A

<table>
<tr><td>Interviewer: Tahsin Atmaca
Interviewee: Business User A</td><td>Date: 23.06.2022</td></tr>
<tr><td colspan="2">General Information: The interview was conducted in German and the following transcript was translated into English.</td></tr>
<tr><td></td><td></td></tr>
<tr><td>Q1</td><td>What is your current position in the company?</td></tr>
<tr><td colspan="2">Head of Data Analytics (Team Leader for Data Analytics Team in Corporate IT)</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td>Q2</td><td>How many years have you worked in this position and how many years have you been in the industry?</td></tr>
<tr><td colspan="2">Two years. I've been working at Claas for four years, and before that, I was employed as a Data Scientist for two years.</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td>Q3</td><td>Can you describe what kind of information you use regularly in your work?</td></tr>
<tr><td colspan="2">We have a four-platform strategy at Glass. There are four main platforms from which the data originates, one is the SAP ERP system, then we have Salesforce for Customer Relationship Management, we have a Microsoft Dynamics environment for the ERP system at the dealer, and we have the DASO platform for engineering for 3D, etc. and we integrate the data all in our backend system (SAP Business Warehouse from Hana). Usually, it is almost always structured data, but there are also use cases with image data or geodata.
As another analytics layer, we also have Azure Databricks as a solution where we store all the mass data, so all the sensor data that comes from the machines, because our machines send data from the field when they are working and active to our backend, and it is stored with us in the Azure Databrick solution.</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td>Q4</td><td>How often do you work with this information and how important is the analysis of this information for your work?</td></tr>
<tr><td colspan="2">This is our main task. In addition to integrating the data in the backends, we support all the departments with analytics, either we train the departments to work in Tableau themselves, as a self-service BI tool, we maintain the Tableau environments, the server, the desktop, etc., provide training, or if the department doesn't want to do it themselves, we also build the dashboard ourselves or have external partners that do it. That's the BI world. On the other hand, in my team, there is also the advanced analytics world, which deals with machine learning topics, and artificial intelligence topics. That's where we develop and integrate ourselves.</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td>Q5</td><td>Do you have information in different reports today that you want to analyze/visualize in the same dashboard?</td></tr>
<tr><td colspan="2">Absolutely. The finance and controlling side in particular is still very much dependent on the Analysis for Office world. We are a long-standing SAP company, and therefore a lot has been developed in the past with SAP tools, so a lot was done with Lumira or with Webi or Analysis for Office. The areas of finance and controlling, in particular, were used intensively. You should rather go in the direction of Tableau, or they have already used SAC in the pilot. They use SAC for a use case/dashboard.</td></tr>
<tr><td colspan="2">(table continues)</td></tr>
</table>

<table>
<tr><td>Q6</td><td>Do you mean that there are a lot of BI tools in use in your company?</td></tr>
<tr><td colspan="2">I wouldn't say that and correct it. In the past, we had a lot of SAP BI tools, because SAP had also constantly brought new tools to the market, but they are discontinued today, so until 2027.</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td>Q7</td><td>Which tools do you then use in your company?</td></tr>
<tr><td colspan="2">Tableau is our one and only next to SAP tools.</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td>Q8</td><td>Do you think that using the preferred software tools would improve your work performance and increase your productivity?</td></tr>
<tr><td colspan="2">That is definitely our strategy to offer only one tool and to fight off the introduction of Power BI or Qlik, because I am convinced myself that it is easier for me as a user if I know, okay, how I can analyze my data, ah yes, with Tableau, that I only have what I can do. Now if I had a choice between Power BI, SAC, or Tableau, I would go with what I can do best, but that introduces complexity that I don't need.</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td>Q9</td><td>If you were to use the integrated cascading dashboard in your work, would you find it useful and could you complete your tasks faster compared to the existing dashboards? In your opinion, what are the advantages and disadvantages of the new solution concept?</td></tr>
<tr><td colspan="2">I think it's good, the linking works. That's also the advantage that they're web tools and if they're well built, it's exactly this form of integrability, which in principle are also unique selling points or advantages. I also thought the solution that you showed was very good, you also couldn't tell which tool you were on, that's also the advantage. I have to say, the only thing that I see as critical, hence my question, it should have the same backend, because then you don't have the risk that the data somehow has differences all at once. That is something that you have to take into account. And you should only use SAC if you also use a feature that you don't have in Tableau. Otherwise, from my point of view, it doesn't make sense to use two tools with one solution. You have shown that SAC has a forecasting function, Tableau can do that too, but if you now show that I can enter data that will be fed back, that will show even more the added value of your solution. Because Tableau can only do something like that with an extension. And that again costs money. But if I have SAC, then I paid for it, and it makes sense to use that. In SAC, you have the advantage that you can write the data back. Generate data and give it back. That also goes in the direction of planning.</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td>Q10</td><td>Would you find the integrated dashboard flexible compared to the previous dashboards? In what ways can the dashboard create (more) flexibility?</td></tr>
<tr><td>Q11</td><td>Would you find the dashboard in this form easy to use compared to previous dashboards? Which dashboard features are particularly user-friendly?</td></tr>
<tr><td colspan="2">For me, it was easy to understand and flexible to use, because I have been working with Tableau for 5 years and know how to recognize the functions and where to look and what you can do. But for beginners, it's always helpful to have an info area that explains a bit about what you can do and how. You can also click on a button now and the graphic gets bigger, which I thought was really nice, but you probably wouldn't figure that out on your own. From the user experience, I think it's very good, it's neat and tidy, you left spaces between the diagrams, that's also very good, a secret tip. As I said, just the hint to add a little info button somewhere to show what all is clickable.</td></tr>
<tr><td colspan="2" align="right">(table continues)</td></tr>
</table>

Q12	**Would this dashboard concept help you in your decision-making? For what reason and in what way?**
I guess you already have drill-down functions and can jump back and filter values, meaning you have all the information to re-evaluate a metric. But whether it's sufficient for business content, I can hardly judge, it depends a bit on the use case. What I still miss is that you don't have the development in the time interval compared to the previous year, because that gives you even more of a sense of where am I in the development, and where can it go.	
Q13	**Do you think this concept can support decision-makers at all levels (vertical axis)? Where do you think the concept can be applied?**
So, I also understood it absolutely, and that is very well implemented. Because I know from the Claas business that there are always phases in the year where there is little activity, but then there is also high again, so the business is seasonal, you can see that better if you compare year by year in the dashboard, otherwise, everything is there that you need to know to recognize the causes and effects and act accordingly.	
Q14	**Have you used similar dashboards before? If so, in what form?**
For sales pipeline analysis, we have a similar dashboard that goes from the top management level to the operational level and back to the base system. That goes in the same direction. Everyone is working on, let's say, an enterprise dashboard or a process-oriented dashboard at the management level, where the key KPIs are shown first and then details are shown with drill-downs. We have such dashboards in different areas.	
Q15	**Even with different tools?**
Not that. But if SAC comes in the future, that's why I think it's good that will also become an issue with us in 1-2 years. Then we have exactly the topic. I can still oppose that we have a classic reporting in it or if we have that now and do the planning there, then I do not want to have to jump again. Then this is where your use case comes into play.	
Q16	**Is there anything you would like to add?**
The authorization question would be the risk here because you have to maintain them twice in both tools. This should also be reconsidered. If you had SAC and Tableau in use, it leads to double maintenance here at the point, in the sense that people have to authorize themselves in some environments. It's an extra step, but it can be done. The use case basically starts in SAC, maybe it would also make sense to embed this in Tableau, that you also have the ability to start the process in Tableau. You also have to think about users who don't have that much IT experience.	

Appendix 21: Interview Protocol Business User B

Interviewer: Tahsin Atmaca Interviewee: Business **User B**	Date: 28.06.2022
General Information: The interview was conducted in German and the following transcript was translated into English.	
Q1	**What is your current position in the company?**
Application Engineer	
Q2	**How many years have you worked in this position and how many years have you been in the industry?**
For over 15 years as a BI administrator.	
Q3	**Can you describe what kind of information you use regularly in your work?**
In the company, we tend to have more historical data, so actual data, and predictive data is a slower issue that we're dealing with, but it's mostly still actual and planning data in a structured form. Big Data, which is unstructured data, is slowly coming up.	
Q4	**How important is the analysis of this information for your work?**
Very important.	
Q5	**Do you have information in different reports today that you want to analyze/visualize in the same dashboard?**
Yes, there have also been longstanding calls for some sort of document flow, including in reporting, to be able to track it.	
Q6	**Which BI tools do you already have experience with, or which tools do you use in your company? Do you think that using the preferred software tools would improve your work performance and increase your productivity?**
SAC, Power BI and SAP BEx are the most common of these. These are our main components. Using preferred tools improves work performance and increases productivity in any case, because you work with the tool you are comfortable and experienced with. You can easily find many functions and it is more fun.	
Q7	**If you were to use the integrated cascading dashboard in your work, would you find it useful and could you complete your tasks faster compared to the existing dashboards? In your opinion, what are the advantages and disadvantages of the new solution concept?**
It will definitely improve and support. I think for a department it will definitely be supportive. If you stay on one interface and have certain possibilities to go down into the details. And especially having the feeling of being on the same dashboard. You don't break out; you don't have to download something and analyze it further somewhere else.	
Q8	**Would you find the integrated dashboard flexible compared to the previous dashboards? In what ways can the dashboard create (more) flexibility?** (table continues)

Q9	Would you find the dashboard in this form easy to use compared to previous dashboards? Which dashboard features are particularly user-friendly?
In any case, it's intuitive. You are guided through the story and automatically move one level deeper. That's definitely positive. The home button is very good in that you can get back to where you started. It wasn't cluttered, you don't get knocked over.	
Q10	**Would this dashboard concept help you in your decision-making? For what reason and in what way?**
It will certainly and the reason is that it corresponds to the approach of guided Analytics. It is usually the case that a key user is someone who knows what he is doing, but you always have to put yourself in the role of the user who does not work with a dashboard every day and who is not familiar with the navigation of the SAC or the content, and you have to give him a way to get information, and you can do that very well with Guided Analytics. For power users or key users, I have different requirements, they approach it differently, but for normal report consumers, this is a very good practice. They also find it very helpful. We always say that we are catering to the field, I think that sums it up quite well.	
Q11	**Do you think this concept can support decision-makers at all levels (vertical axis)? Where do you think the concept can be applied?**
There, too, I can bring the focus, I mean, we now have a dashboard on different levels, first the management dashboard, then the national company and then below that, I'll say, the data servant, who really has to work outside on the system. Users who are with us today at the detail level are building their own dashboards because there's not enough IT capacity, or because the systems are not available, they're helping themselves in other ways. Of course, SAP also has a certain overhead, I have Excel and I have data in there and I can quickly create a reporting, whereas now in Power Bi, for example, we don't necessarily have. But in terms of the three levels, I think that's definitely an applicable example. In our case I see the practical application very strongly, what we send today by broadcasting as a workbook is mapped similarly in this form, only with more interactivity. What is programmed today in the workbooks is pure with Excel, i.e., masses of BW data hidden in Excel, and you do interactivity with Excel.	
Q12	**Have you used similar dashboards before? If so, in what form?**
We have built such in the construction in which we go into several levels. The first approaches are there, while the direct connection with parameters is not yet, but that is definitely a point that will be subject.	
Q13	**Could you also imagine implementing such a solution concept in your company/department/team?**
Yes definitely.	
Q14	**Is there anything you would like to add?**
Analysis for Office is probably also conceivable, instead of the Tableau report. Then we would have the point that I can also go down into the detail report in Query and say I have a handoff, this is my customer, this is my invoice, and show me detailed information from another data pot. That would certainly be a conceivably good approach for us. It would be very helpful for us to get the presentation or the master's thesis as food for thought when we're looking at this in the company.	

Appendix 22: Interview Protocol Business User C

Interviewer: Tahsin Atmaca Interviewee: Business **User C**	Date: 29.06.2022
General Information: The interview was conducted in German and the following transcript was translated into English.	
Q1	**What is your current position in the company?**
I am at Claas in the sales company and my department is Sales Network Development. We are responsible for the CRM system and I am mainly responsible for reporting in the CRM system for the German sales company.	
Q2	**How many years have you worked in this position and how many years have you been in the industry?**
For 5 years now. I've been in the department here longer and over time I've gotten more involved in reporting.	
Q3	**Can you describe what kind of information you use regularly in your work?**
We are pretty much in the single data set, so miles away from mass data. It is always the individual data set that is crucial in our work here. Our data is structured by the CRM system, and we perform the analysis behind it. It is mostly historical data, i.e. actual data.	
Q4	**How often do you work with this information and how important is the analysis of this information for your work?**
It is not the case that the data is updated hourly, but we work daily because the reporting is updated once overnight. The analysis is very important because this data is used for sales management to make decisions.	
Q5	**Do you have information in different reports today that you want to analyze/visualize in the same dashboard?**
Yes, precisely because we are converting the CRM system from SAP to Salesforce into the cloud, and we are doing this worldwide, which means that the entire reporting is also being restructured. In all its variants, the restructuring of the data, new basis, new dashboards, new tools, and new applications. And here we want to create reports that are mapped into an integrated dashboard system.	
Q6	**Which BI tools do you already have experience with, or which tools do you use in your company? Do you think that using the preferred software tools would improve your work performance and increase your productivity?**
We used to use SAP solutions (Lumira, Analysis for Office), and we also used a BI tool called Apteco. That's also a data analysis tool, but it's mainly used for selection, not so much for visualization. That was also on top of the CRM system, that's where the data was processed, and we used that as well. And now Tableau has been added as well. Due to the Claas strategy, we are now moving away from Apteco's BI tool. I think that by using the preferred tool, there will be less effort to engage external service providers, with whom the data will be discussed, and distribution and time will be lower. But on a gut level, I would say that the actual work in Tableau for just this use case will take longer. (table continues)	

Because that's a use case that's made for selection, and Tableau can select, of course, but I don't think it's made for that at its core. So this step will take longer because of the conversion to Tableau. Besides that, I would say that the replacement of the reporting system, that is, the replacement of SAP and the changeover to Tableau, will, in my opinion, lead to a significant improvement in many areas. First of all, a lot more people will be able to work with it, whereas before it was just bundled in IT, so we will gain momentum, people handling it, visualization, and so on. We will become much faster and better.	
Q7	**If you were to use the integrated cascading dashboard in your work, would you find it useful and could you complete your tasks faster compared to the existing dashboards? In your opinion, what are the advantages and disadvantages of the new solution concept?**
Yes, I think that would be of interest here. What we are not used to at all at the moment is that the colleagues themselves sit in front and click a lot, which is also the strength here, storytelling in the reporting. That's something we're not used to yet and haven't learned yet. Because before, the reports were relatively rigid, there was a lot of reworking and PDF variants were sent by e-mail. So this is a real change for management. The interest would also be there immediately if it also worked well, but the behavior is not really learned at the moment. But nevertheless, the information is very broad in this representation, which can be reached by it through. It is currently only possible web-based, hence a point of criticism, and performance plays an important role. The dummy data is finite and the performance is relatively good here, but when more information comes in, the performance goes down quickly. And then it's no longer fun to click around in an agile way. I think these are the disadvantages of live reporting.	
Q8	**Would you find the integrated dashboard flexible compared to the previous dashboards? In what ways can the dashboard create (more) flexibility?**
Q9	**Would you find the dashboard in this form easy to use compared to previous dashboards? Which dashboard features are particularly user-friendly?**
From the feel of it, the filters were hidden for me, but if you know where they are, you can definitely find them. It doesn't feel as integrated into the dashboard to me. SAP's augmented analytics capabilities are very nice, but I mean there are very few use cases right now where AI is used in creating a dashboard. You actually have a pretty clear picture of what you want to report. But I think that's exactly the point, that most users have to get used to the fact that there is such a thing, and that they might have to play a little bit with the data, dive in a little bit themselves, and not always get a ready-made dashboard. The technology is good, but the use cases are not there yet.	
Q10	**Would this dashboard concept help you in your decision-making? For what reason and in what way?**
Actually, it's like a focus report, and that's great, of course. All the reports we produce also follow the same logic of going from big to small. Personally, I agree that management doesn't look at all the metrics every time they look at them. Probably four days out of five they just take a look at them, and on the fifth day they analyze them further, and I think that structure is very helpful.	

(table continues)

Q11	**Do you think this concept can support decision-makers at all levels (vertical axis)? Where do you think the concept can be applied?**
I think it's helpful if you can address multiple levels, and especially it's helpful if as many people as possible can work with the exact same dashboard, and when top management is talking to middle management, that they're both looking at it, or when middle management is talking to lower management, that they're looking at it exactly and they all know where to click and where the relevant numbers are that are being talked about, and not everyone is somehow presented with a different sheet where the same numbers are again, but arranged differently, with different colors, that I think that kind of approach helps enormously.	
Q12	**Have you used similar dashboards before? If so, in what form?**
Dashboard with drill-downs so enters in more levels that definitely, but with multiple tools that unfortunately not.	
Q13	**Could you also imagine implementing such a solution concept in your company/department/team?**
First of all, I would think why not. The fact that something like this works at all is very good. The added value that SAC has compared to Tableau is unfortunately difficult for me to assess. If you have a use case that this approach helps, why not. Permissions of course also play a role, if it works to some extent then the concept can work. However, this is often a difficult issue. The dashboards need to access the same DWH, where permissions are then governed.	
Q14	**Is there anything you would like to add?**
What is often underestimated, that it also finds application, is that you manage to bring this to the masses. Not just making it accessible to people, there are a lot of very good tools that are brought in with AI, with great dashboards, etc., but then little is used closer. I think the transition often finds too little time. That management is serious about it as well. There's a lot of investment, but people end up looking at their Excel spreadsheets again. I think this transition is often underestimated.	

Appendix 23: Interview Protocol Business User D

Interviewer: Tahsin Atmaca Interviewee: Business **User D**	Date: 29.06.2022
General Information: The interview was conducted in German and the following transcript was translated into English.	
Q1	**What is your current position in the company?**
Specialist Quality Controlling	
Q2	**How many years have you worked in this position and how many years have you been in the industry?**
I've been working at Porsche for 8 years, and I began my career here.	
Q3	**Can you describe what kind of information you use regularly in your work?**
Warranty data is the main business, i.e. warranty claims, workshop data, vehicle information, and quality data from development, production and sales. In our day-to-day business, we usually work with structured data, but there is also unstructured data.	
Q4	**How important is the analysis of this information for your work?**
The analysis is very important because when the key figures are presented to top management, it always leads to questions about why the development is the way it is, whether particularly good or bad. And you have to analyze the chain from top to bottom every day to explain the deviation.	
Q5	**Do you have information in different reports today that you want to analyze/visualize in the same dashboard?**
Yes, we have a project there at the moment where we have different metrics. We have various key figures, each of which we have for ourselves, and we are trying to bring them closer to management in the form of a dashboard. It has to be said that in a dashboard, the information is consolidated, not simply placed next to each other, moreover, the logic behind the individual dashboard is also transferred in a certain way. It would not be enough if we simply linked the dashboards, but we also have to transport and translate the context.	
Q6	**Can we call such thing storytelling?**
Absolutely, that's what the merged dashboard should offer.	
Q7	**Which BI tools do you already have experience with, or which tools do you use in your company? Do you think that using the preferred software tools would improve your work performance and increase your productivity?**
In our field, we use SAC and Tableau, in the company we also use Qlik. I think the BI tools can do the same meanwhile, but they have some “tricks”, so in my job or profession you can't avoid specializing in one or at least get more expertise. If you only create dashboards, then maybe not, but if you also want to analyze the data, it's important to work with the dashboard that you know as an expert. That is exactly the idea of this concept, that we say that the specialist department knows a tool very well and can work with it very well. Then it is a nuisance to have to deal with other tools. (table continues)	

<table>
<tr><td colspan="2">So he can work in his department with the tool of his choice and if the management prefers another tool, then the management can still use another tool and navigate down. But the department can continue to use their preferred tool without having to learn another tool as well.
The story at the individual level, but also in breadth should be adjusted. I.e. you notice that it is different navigation, here it is indeed a clean record, but in practice, it is often not the case. Just that the vehicles or the projects remain the same, that for example the fields behind the filters are called the same, and that is of course a big challenge. It may be possible to solve it in such a way that in rare cases you make a continuous chain that goes from the very top to the very bottom, and if middle management has a question, you take a deep dive directly into Tableau.</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td>Q8</td><td>If you were to use the integrated cascading dashboard in your work, would you find it useful and could you complete your tasks faster compared to the existing dashboards? In your opinion, what are the advantages and disadvantages of the new solution concept?</td></tr>
<tr><td colspan="2">Yes, I think it makes sense, for example, the top management has even more access to even more different areas than we do, and the tool can play out its advantages, even more, when it is specified at different levels. So, for a concrete example, we have only one management tool in SAC. If we can go to the export level and pick up the same data there with Tableau, that would be very good. I could imagine something like that. That would also be a big advantage.
One disadvantage is the ongoing maintenance of two tools. You always have to see if you get the regular updates, etc. And when you have a change, it's not just in Dashboard 1 and Dashboard 2, but also in the transition from Dashboard 1 to 2.</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td>Q9</td><td>Would you find the integrated dashboard flexible compared to the previous dashboards? In what ways can the dashboard create (more) flexibility?</td></tr>
<tr><td colspan="2">So in terms of flexibility, I felt that in the deep dive view, it was already built on middle/lower management. I think this is where we would bring in more capabilities to do the deep dive, like dimensions, more filters, search windows, text search, etc...
We also found that if you put everything on one database, i.e., top management and the absolute deep dive at the lower level, sometimes there can be data issues. When you have the all-encompassing solution and from a management perspective it's about aggregation, it's about computation, it's about fast availability, it's about performance, it's a challenge. Flexibility is usually an expensive buy with performance.</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td>Q10</td><td>Would you find the dashboard in this form easy to use compared to previous dashboards? Which dashboard features are particularly user-friendly?</td></tr>
<tr><td colspan="2">On most websites, I find filters either on the left or on the right. Intuitively, I would always search there. I don't find it quite as intuitive. It doesn't quite stand out from the header in my opinion.
What I find very good is the panel board, which is set up like the "Netflix page", that you have a clear structure on the overview page and know where to find what.</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td>Q11</td><td>Would this dashboard concept help you in your decision-making? For what reason and in what way?

(table continues)</td></tr>
</table>

Q12	**Do you think this concept can support decision-makers at all levels (vertical axis)? Where do you think the concept can be applied?**
What question does it answer and what do I control with it? This is the link between the dashboards. So why did I choose this report and not another? And context is always very important here. When I look at the KPIs, I can look at them in isolation, but that doesn't give me the whole picture. The whole picture comes when I put everything on top of each other. Going back to your example: I can think of other KPIs that would be important for manufacturing decision-making.	
Q13	**Have you used similar dashboards before? If so, in what form?**
We have dashboards where we do storytelling, but we haven't linked it in that form yet. We link from SharePoint to Tableau from time to time, but not in this form.	
Q14	**Could you also imagine implementing such a solution concept in your company/department/team?**
Yes, absolutely, if a department is already working with a different tool than e.g. the management, then such a concept could be implemented.	
Q15	**Is there anything you would like to add?**
The authorization concept is already relatively painful with one BI tool, and that should not be forgotten here. Here, you certainly have double maintenance. But I still find it exciting, and I already have a few use cases in mind where I think this concept can be applied here. May I come back to you here?	

Appendix 24: Encoding references

Character	From Windows-1252	From UTF-8
space	20%	20%
!	21%	21%
"	22%	22%
#	23%	23%
$	24%	24%
%	25%	25%
&	26%	26%
'	27%	27%
(	28%	28%
)	29%	29%
*	%2A	%2A
+	%2B	%2B
,	%2C	%2C
-	%2D	%2D
.	%2E	%2E
/	%2F	%2F
:	%3A	%3A
;	%3B	%3B
<	%3C	%3C
=	%3D	%3D
>	%3E	%3E
?	%3F	%3F
@	40%	40%
[	%5B	%5B
\	%5C	%5C
]	%5D	%5D
^	%5E	%5E
_	%5F	%5F
{	%7B	%7B
|	%7C	%7C
}	%7D	%7D
‘	91%	%E2%80%98
’	92%	%E2%80%99
“	93%	%E2%80%9C
”	94%	%E2%80%9D
–	96%	%E2%80%93