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Analysis and Implementation of a Business Intelligence Application for Logistic and Procurement Management

Sews Cabind case for the shortage problem

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Summary

INTRODUCTION

In today's world, we witness constant technological innovations that are significantly changing not only our lives, but also the ways in which business operations are conducted. Companies use multiple applications and tools to manage their daily activities (CRM, ERP, Office Suite, BI, …) and each of these applications can store, analyse or modify certain types of data, that are not necessarily compatible with each other. In addition, each office, team or department may use several applications, which may differ from those used by other corporate structures. The amount of data created every day is enormous, just think that the 90% of the data around the world was created in the past two years against the 10% created over the whole humanity existence period, and this trend is not going to change, the amount of data created every day is constantly growing. Organizations have more data than ever at their disposal and the access to data-driven tools enable them to gather more information about their stakeholders. For companies all this information is essential, they give better control and visibility over the companies processes and they allow them to predict unforeseen challenges and act accordingly. Nowadays is evident that a correct exploitation of data can create a concrete possibility to gain competitive advantage over competitors.

By the way the volume of data collected or created, the lack of standardisation and the multiplicity of applications used make it difficult for the company's decision-makers to exploit and analyse the data globally. The main purpose of business intelligence is precisely to find a solution to this problem. In recent years, more and more companies have started to invest in this direction, and nowadays it has become very difficult to find a medium-sized or large company that does not rely on this technology. Also, from the solutions providers side, many companies have entered this market, increasing its competitiveness and pushing forward the need to offer increasingly innovative

products. BI today is not just about providing visibility or monitoring business processes, but has become an integral part of them.

The main purpose of this paper is properly this, explaining how Business Intelligence influenced and became integral part of business processes. In order to give a concrete example of this we will present the case of Sews Cabind, company where I did an internship, that adopt the BI software QlikView.

- In the first chapter we will explain what is Business Intelligence providing its definition and describing the differences with some related terms, we will also review the history of this technology with a focus on the main constraints that limited its development and how these have been overcome thanks to the parallel technological progress of the hardware systems behind it.
- In the second chapter we will focus on the architecture of a BI system, describing the stages of BI process and the hardware technology behind it.
- In the third chapter we will propose some of the main application and tools of BI in order to give an overview of its possible usage within the corporate environment.
- In the fourth and last chapter, we will retrace the path followed so far but this time we will do it for a specific real-life case. We will start by presenting the company Sews Cabind, analysing its history, organisation and production process. We will move on to talk about the supply chain issues in its industry and how the semiconductor crisis that occurred during the COVID has accentuated its effects. Finally, we will show how QlikView's Shortage application has helped to mitigate these issues and how it embedded itself within business processes.

1. CHAPTER: BUSINESS INTELLIGENCE HISTORY AND DEFINITION

The first steps will show a still primordial state of BI but are useful to understand which were the needs that later led to the development of this technology. Then we will go on showing successive prototypes until we will reach the latest BI technologies of today. As we will see the advancement of the business intelligence is strictly related to the advancement in the technology behind it, in other words, as infrastructure hardware technology progresses, BI technology will develop exponentially.

1.1) **BI definition and related terms**

The term Business Intelligence was coined in 1989 by Howard J. Dresner, analyst at Gartner Group, who characterized it as a collection of "*concepts and methods to improve business decision making by using fact-based support systems*." Here he highlights the importance of data analysis, reporting and query tools that users can use when processing large amounts of data and that help them synthesize valuable and useful information.[1]

The term business intelligence, in nowadays, covers a much wider field, although the final purpose is still the same, helping business user to make data-driven decisions, it

[1] Elena, Cebotarean*.: Business Intelligence*. In: Journal of Knowledge Management, Economics and Infomration Technology. [online]. <http://www.scientificpapers.org/wp-content/files/1102_Business_intelligence.pdf>

may have different meaning depending on the perspective by which it is seen. Indeed, BI can be interpreted as a business process, as a software, or even as a technology.[2]

When it is meant as business process, BI refers to the systematic approach of collecting, analyzing, and utilizing data to drive decision-making within an organization. It involves identifying relevant data sources, extracting, and transforming data, performing data analysis, and presenting insights to stakeholders.[3]

From another perspective, BI as a technology encompasses the tools, technologies, and infrastructure used to support the collection, storage, processing, and analysis of data. This includes databases, data warehouses, data integration tools, reporting and analytics software, dashboards, and other technologies that enable efficient management and utilization of data.[4]

Finally BI as software refers to specialized applications and platforms designed to facilitate data analysis, reporting, and visualization.[5] Examples of popular business intelligence software include Tableau, Power BI, QlikView, and MicroStrategy.

So, in order to give a complete definition, we must put together all the different points of view, and a complete definition is:

"*Business intelligence (BI) is a broad category of applications, technologies, and processes for gathering, storing, accessing, and analyzing data to help business users make better decisions.*"[6]

[2] Stedman, Craig.: *Business Intelligence.* [online]. <https://www.techtarget.com/searchbusinessanalytics/definition/business-intelligence-BI>
[3] Warehouse Logistic.: *Definition Business Intelligence System*. [online]. <https://www.warehouse-logistics.com/en/definition-bi.html>
[4] Pratt, K., Mary.: *Business Intelligence architecture*. [online]. <https://www.techtarget.com/searchbusinessanalytics/definition/business-intelligence-architecture>
[5] IBM.: *What is Business Intelligence?* [online]. <https://www.warehouse-logistics.com/en/definition-bi.html>
[6] Watson, Hugh.: *Business Intelligence: Past, Present and Future*. In: Communications of the Association for Information Systems. Vol. 25. 2009. p. 491

Part of Business Intelligence involves also performing different kinds of analytics in order to gain insight from the data. From this point of view often, business intelligence is confused and used interchangeably with Business analytics.[7]

Business Analytics is a more generic term, because it includes a wide range of activities all related to the business, from data exploration to advanced analysis and decision modelling, among others. There are different types of analytics such as descriptive, diagnostic, predictive and prescriptive analytics.

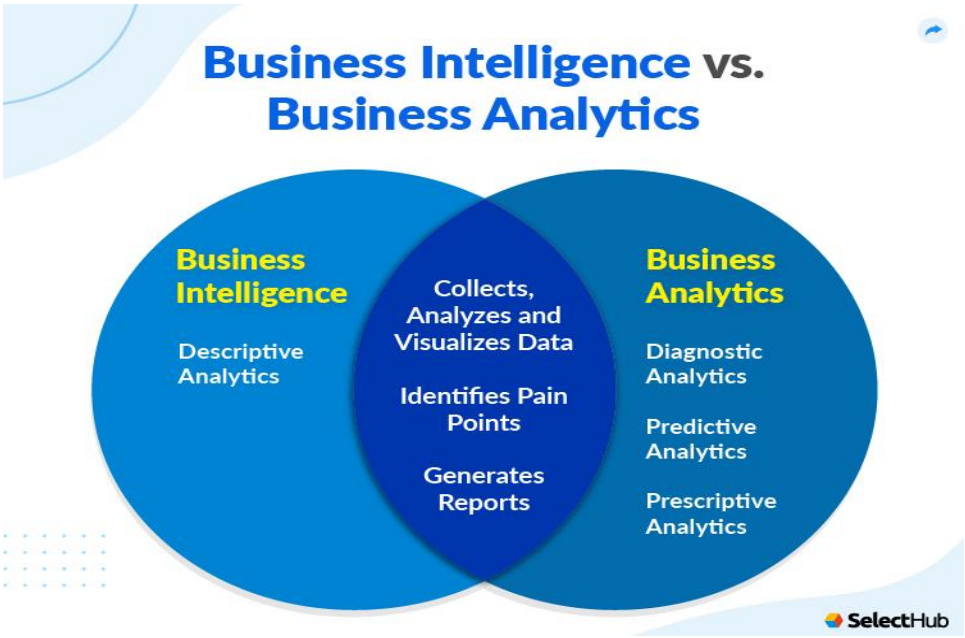

Figure 1. 1 Representation of the main differences and similarities between business intelligence and business analytics

Business Intelligence focuses on descriptive analytics. The goal of Descriptive Analytics is to provide historical and current data that helps businesses to monitor their operations, track performance, and gain insight into their past and current operations. Data that support the decision-making process thanks to BI are collected, stored, analysed, and presented in the form of reports, dashboards, and visualizations, in this way, even large amount of data is summarized and presented in a meaningful way. Business users, at this point, are able to understand all the patterns, trends and relationships emerging from the data.

[7] Analytix Labs.: *Business Intelligence vs. Business Analytics: What Are The Differences?*. [online]. <https://www.analytixlabs.co.in/blog/business-intelligence-vs-business-analytics/>

On the other hand, BA's goal is not mainly to monitor and track the situation, but to enable companies make decisions that are supported by analysis and data. BA includes three different forms of analytics: descriptive analytics, predictive analytics, and prescriptive analytics.

Predictive analytics is used especially when a company wants to somehow predict future consumer behaviour or business results. It is a type of data analysis that uses advanced machine learning algorithms to identify patterns, behaviours and trends in amounts of historical data. The company can thus better satisfy the needs of their customers.

Prescriptive Analytics recommends optimal practices to achieve desired results. It uses techniques such as optimization, simulation, and decision modelling to evaluate different scenarios and propose the best possible actions to achieve specific goals. Prescriptive analytics helps businesses make decisions that are optimized for desired outcomes, considering various constraints, resources, and goals.

The last type of analytics is the diagnostic analytics, it helps businesses gain insight into the causes of individual situations using techniques including data drilling or data mining.

In conclusion, Business intelligence is typically broader in scope and provides historical and current data for operational decision-making, while business analytics tends to involve more advanced techniques, has a future-oriented perspective, and is used for strategic decision-making.

1.2) **First BI mentions**

Before the development of modern technologies and the onset of the information age, many traders and entrepreneurs relied just on their instincts for their decision-making. But that has changed with the advent of modern technology and the associated business intelligence. The term "Business Intelligence" was used for the first time in 1865, when the historian R. M. Devens applied this term in his "*Cyclopædia of Commercial and*

Business Anecdotes." The term was used in connection with the profit that came from gathering information and making decisions based on it. This drew attention to the fact that the formulation of business strategies no longer relied only on instinct but started to be based mainly on data and empirical evidence.[8]

By the early 20th century the cities started to be more industrialized, plenty of factories and production plants arised, together with the need to improve operiational performances. This leaded to the first ideologies of scientific management. The first systems of business analysis are mostly attributed to the American mechanical engineer, Frederic Taylor, who invented an approach, that combined statistical measures, efficiency and rationality to the process and people management problems.[9] His scientific management was focused on studying and analyzing the production technique and body movement of the workers in order to find the way that would help to increase industrial production.[10]

Taylor was among the first of the management consultants and eventually started to monitor the production lines at Henry´s Ford factory, by keeping track of the time to complete each component of the assembly line, to improve performance. This is often reffered as an modern example of business analysis. Taylor's work and success could be said to have revolutionized the manufacturing industry worldwide.[11]

[8] Limp, Paulo.: *Exploring the History of Business Intelligence*. [online]. <https://www.toptal.com/project-managers/it/history-of-business-intelligence>
[9] Mortenson, J. Michael. et. al.: *Operational research from Taylorism to Terabytes: A research agenda for the analytics age*. In: European Journal of Operational Research. Vol. 241, Issue 3. 2015. p. 583-595
[10] Limp, Paulo.: *Exploring the History of Business Intelligence*. [online]. <https://www.toptal.com/project-managers/it/history-of-business-intelligence>
[11] Analytix Labs.: *Business Analytics : The Past and the Future*. [online]. <https://www.analytixlabs.co.in/blog/business-analytics-the-past-and-the-future/>

1.3) **Emergence of Computers**

In the 1930s, the first electronic computers began to be created, but they were still very inefficient compared to today's ones. The rapid development of computers was mainly caused by the influence of the Second World War with the aim of breaking the enemy's codes. Until the 1950s, computers primarily used punched cards or punched tapes for data storage.[12] Punched cards or tapes were stacks of cards with small holes that stored data in machine language. This data represented information to be processed by computers.[13] However, programming and data storage required a lot of cards and manual labor, since one punched card could only store 80 bytes of data.[14]

Figure 1.2 Example of a punchcard for data store

[12] Limp, Paulo.: *Exploring the History of Business Intelligence*. [online]. <https://www.toptal.com/project-managers/it/history-of-business-intelligence>
[13] Foote, D. Keith.: *A Brief History of Data Storage.* [online]. <https://www.dataversity.net/brief-history-data-storage/>
[14] Google Arts & Culture.: *From Punch Cards to the Cloud*. [online]. <https://artsandculture.google.com/story/from-punch-cards-to-the-cloud/VQXBq16p7orTYw>

As a result of the post-World War II boom and due to the rapidly growing amount of technological and scientific data, the need to organize and simplify this information has constantly grown. The hard disk, which was invented by IBM in 1956, made it possible for the first time in history to store a large amount of data.[15]

Two years later, IBM researcher Hans Peter Luhn published an article titled "*A Business Intelligence System*". In his article he illustrated one system that was able to spread information throughout different sectors of an organization. Luhn also cited the definition of business intelligence from Websters Dictionary (famous American dictionary of English language): "*the ability to apprehend the interrelationships of presented facts in such a way as to guide action towards a desired goal*."[16] His work is of great relevance today, as he foresaw several trends in business intelligence that are leading today, such as the ability of information systems to learn and predict based on users´ interest. Today we call it machine learning. Luhn is widely regarded as the "*father of business intelligence*."[17]

Even though this concept was attractive to several stakeholders, it was not possible to use it practically at the time due to high financial costs. Several technological advances were necessary for this concept to be adapted.[18]

Although computers initially represented huge machines that needed to be controlled by a few experts, their use to extract conclusions from data became an increasingly common phenomenon. However, the primary problem was that there was no method that would centralize all the data in one place and there was no way to access the computer and its data outside the IT space. The first database systems enabled the first

[15] Limp, Paulo.: *Exploring the History of Business Intelligence*. [online]. <https://www.toptal.com/project-managers/it/history-of-business-intelligence>
[16] Luhn, P. Hans.: *A Business Intelligence System.* In: IBM Journal. 1958. [online]. <http://altaplana.com/ibm-luhn58-BusinessIntelligence.pdf>
[17] Heize, Justin.: *History of Business Intelligence*. [online]. <ttp://www.bisoftwareinsight.com/history_of_business_intelligence/>
[18] Limp, Paulo.: *Exploring the History of Business Intelligence.* [online]. <https://www.toptal.com/project-managers/it/history-of-business-intelligence>

data searches using binary trees and solved the problem that data itself had previously failed to generate statistics.[19] The first computer applications that processed transactions, and were used mainly for scientific purposes, were developed in the 1960s. Even though the reports did not provide detailed information, they helped in a certain way in decision-making processes. The late 1960s and early 1970s saw a boom in the development of various applications that helped support decision-making. Decision support systems (DSS) have begun to be used to describe these applications.[20]

1.4) **Big Players: Sap, IBM and First BI devices**

Before the boom in the development of decision support applications, in 1968, data was processed exclusively by experts who had specialized skills. However, the interpretation of these data was very disjointed and chaotic, as the data was drawn from several sources. In 1970, E. Codd of IBM, recognised the problem and published the paper "*A Relational Model of Data for Large Shared Data Banks*", paving the way for a new generation of databases.[21] This fact can be considered the greatest achievement of the 1970s because it changed the way databases were designed. Databases have become "*a tool for querying data to find relations hidden within*". This idea greatly simplified the way people accessed data.[22] Many industry players and even some new entrants have been inspired by this new concept. For the first time the market of Business Intelligence became attractive, and many actors joined the industry. These

[19] Limp, Paulo.: *Exploring the History of Business Intelligence*. [online]. <https://www.toptal.com/project-managers/it/history-of-business-intelligence>
[20] Watson, J. Hugh.: *Business Intelligence: Past, Present and Future*. In: Communications of the Association for Information Systems. Vol. 25. Article 39. 2009. p. 488
[21] Foote, D. Keith*.: A Brief History of Business Intelligence*. [online]. <https://www.dataversity.net/brief-history-business-intelligence/>
[22] Dataconomy.: *The History of BI: The 1960's and 70's*. [online]. <https://dataconomy.com/2014/06/20/history-bi-1960s-70s/>

include SAP, Siebel and JD Edwards, the latter two after founded the Oracle corporation.[23]

The main problem was that these databases suffered from "silo" problems. Because they were very one-dimensional, the flexibility of their use was very limited. Even as simple as coding cities in "OH, NJ and NY" on one database and using "Ohio, New Jersey and New York" on the other made difficult task for cross-linking.[24]

As mentioned earlier, the systems were not easy to use because they were one-dimensional and had very limited flexibility. Despite this, more and more companies were able to improve this system. One of the most famous from this period was Nielsen. The Nielsen rating, which served as a marketing tool, measured the viewership of television programs in households with the use of Audimeter. This device was connected to the television and was recording which channel was being watched. Even though these ratings were the most watched in the industry, Nielsen was able to further improve the system by introducing the Storage Instantaneous Audimeter, which could evaluate ratings in just 36 hours, while the older system took two weeks for the same activity. In the late 1970s, the first commercial version of the Oracle database was launched. It was a system that replaced the databases used until then, with its technology, which allowed much greater flexibility in searching and a lower price for storage. It was the first real relational database management system on the market. This technology set trends and dictated advances in BI for decades to come.[25]

[23] Lago, Cristina.: 150 years of business intelligence: A brief history. [online]. <https://www.cio.com/article/221963/history-of-business-intelligence.html>
[24] Limp, Paulo.: *Exploring the History of Business Intelligence*. [online]. <https://www.toptal.com/project-managers/it/history-of-business-intelligence>
[25] Limp, Paulo.: *Exploring the History of Business Intelligence*. [online]. <https://www.toptal.com/project-managers/it/history-of-business-intelligence>

1.5) **Business Intelligence 1.0: first BI software**

In the 1980s, the number of BI vendors grew rapidly, databases were constantly evolving and made it possible to accumulate information from various sources into a single database. The new high level of competition in the market pushed down the prices for storage and consequently better databases enabled a new generation of business intelligence solutions.[26] R. Kimball and B. Inmon proposed two different, but similar strategies for the problem of managing data from different sources, to make analysis. Even though the approaches of the authors are different, they both agree that data can be stored in one place within the framework of complete integration, even though they come from different sources. This new technology was the data warehouse.[27] Data warehouses are databases that collect large amounts of data coming from other sources, usually other databases, which deepens the possibility of analysis with the ability to cross-reference these different sources. The discovery of data warehouses was the most important milestone of this period. Of course, this advanced system cannot be compared with current technology because it was overly technical and expensive. Management and maintenance of the reports required the presence of several expensive computer technicians.[28] On the other hand, with the help of data warehouses, the time required to access the data has been reduced. Simply, the data, which until now was spread out in several places, was available in one place.[29]

Despite these problems, business intelligence became an integral part of the tools available for decision making. Top management at the time depended on the results of

[26]Velosa, Andrés. et. al.: *Business Intelligence and its big evolution*. In: Preprints.org. 2021. 2021030584. 2021
[27] Lago, Cristina.: *150 years of business intelligence: A brief history*. [online]. <https://www.cio.com/article/221963/history-of-business-intelligence.html>
[28] Biere, Mike.: *Business Intelligence for the Enterprise*. Chapter 3. In: IBM Press. 2003. ISBN: 9780131413030.
[29] Heize, Justin.: *History of Business Intelligence*. [online]. <ttp://www.bisoftwareinsight.com/history_of_business_intelligence/>

BI solutions such as Crystal Reports and MicroStrategy, and Microsoft Excel (released in 1985) was starting to be used in every company.[30]

Over time, in the 1990s, when the cost of maintaining data warehouses fell due to the increase in market competition and improved knowledge of IT professionals with technology, data became available not only for top management but also to company employees. We call this period "Business Intelligence 1.0".[31]

The problem of this era was that asking new questions was still very expensive, and even though the answer was quickly available, it was very specific and not satisfying all the user's needs. To reduce this problem new BI tool were developed, enabling more detailed answers. The most popular tools were for transformation, extract, and load (ETL) and analytical processing (OLAP). Development of these tools were mainly to speed up processes.[32] To this day, ETL and OLAP tools are still a crucial part of business intelligence solutions (in Chapter 2, they will be described in detail).

During this period, among other things, enterprise resource planning (ERP) systems, which combine various applications to manage aspects of a business, became popular. Today, these systems are widely used in almost every company and are an integral part of it. In the late 1990s, Microsoft introduced the new Windows 95 operating system, and computers became part of our everyday life also in the households.[33]

[30] Limp, Paulo.: *Exploring the History of Business Intelligence*. [online]. <https://www.toptal.com/project-managers/it/history-of-business-intelligence>
[31] Limp, Paulo.: *Exploring the History of Business Intelligence*. [online]. <https://www.toptal.com/project-managers/it/history-of-business-intelligence>
[32] Heize, Justin.: *History of Business Intelligence*. [online]. <ttp://www.bisoftwareinsight.com/history_of_business_intelligence/>
[33] Limp, Paulo.: *Exploring the History of Business Intelligence*. [online]. <https://www.toptal.com/project-managers/it/history-of-business-intelligence>

1.6) **Business Intelligence 2.0: disruption in the new millennium**

At the beginning of the new millennium, also known as Business Intelligence 2.0, the use of business intelligence was already a condition for companies, if they wanted to stay on the market and remain competitive.[34] All large and medium-sized enterprises considered business intelligence solutions to be mandatory equipment, and a strong concentration of competition began to form, especially in enterprises such as IBM, Microsoft, SAP and Oracle.[35]

The motivation to further develop BI tools was mainly focused on increasing their speed and the form in which the data will be provided, so that they are not difficult even for a person who does not have a technical education. Thanks to predictive analytics, businesses began to predict future changes, cloud technologies and software enabled the way data is presented, and social media such as Facebook or Twitter began to offer new opportunities to share ideas and opinions that were freely available on the Internet. These information were easy to collect and analyze.[36]

BI 2.0 was filled with many technologies that could incorporate real-time data so that businesses had the most up-to-date information possible, including self-service functions that meant that the IT department was not needed for every task.[37]

Companies in an increasingly connected world needed information to be displayed and incorporated into data warehouses in real time. In 2005, the free web analytics service "*Google Analytics*" made it possible for them. With this fact, the term "*big data*" was also created in the same year, by Roger Magoulas from O'Reilly Media, with the aim of defining "*great amount of data that traditional data management techniques cannot*

[34] Limp, Paulo.*: Exploring the History of Business Intelligence*. [online]. <https://www.toptal.com/project-managers/it/history-of-business-intelligence>
[35] Lago, Cristina.: *150 years of business intelligence: A brief history*. [online]. <https://www.cio.com/article/221963/history-of-business-intelligence.html>
[36] Lago, Cristina.: *150 years of business intelligence: A brief history*. [online]. <https://www.cio.com/article/221963/history-of-business-intelligence.html>
[37] Heize, Justin.: *History of Business Intelligence*. [online]. <ttp://www.bisoftwareinsight.com/history_of_business_intelligence/>

manage and process due to the complexity and size of this data". Companies and enterprises needed to find a way to solve the problem of insufficient storage required for this enormous and ever-growing amount of data. The seeds of cloud computing stem from this very fact.[38]

1.7) **Contemporary and future Uses of BI**

We could say that we are currently in the period of Business Intelligence 3.0, when BI is already a part of every single medium or large company, whether the company is in the field of banking, finance, IT, or communication. BI tools are becoming more and more intuitive, flawless, and slowly acquiring new and new features to improve the efficiency.[39]

Currently, companies are using a really large number of software application, this imply that there is an enormous amount of data that companies must operate with, eventually this data is also stored in different independent data repositories. Even though technology allows the storage of these data, they require specific dedicated physical area. Cloud computing is nowadays a really common solution to solve the problem of the big amount of data and in a future perspective more and more quantum computers are appearing around the world. Another non-trivial challenge is the quality of data. Data coming for all these different sources is difficult to integrate since often they are structured in different ways.

In order to create unique rules and norms for the data handling around the companies, new concepts such as data governance and data management became popular. These two entities have the responsibility to create and to enforce commonly recognised rules

[38] Limp, Paulo.: *Exploring the History of Business Intelligence*. [online]. <https://www.toptal.com/project-managers/it/history-of-business-intelligence>

[39] Lago, Cristina.: *150 years of business intelligence: A brief history*. [online]. <https://www.cio.com/article/221963/history-of-business-intelligence.html>

and regulations that help the company in the proper use and management of its data. The main challenges of data governance and data management in the last years were data security and data privacy. Indeed, with the rise of cybersecurity threats and data breaches, data security became a critical challenge. It is important to protect sensitive data, ensure appropriate access to information, and prevent intrusions. At the same time also data privacy regulations acquired importance, governments and institution are pushing organizations to protect the privacy rights of their customers and companies are placing more and more emphasis on data governance practices. Ensuring data quality, compliance, and privacy protection are critical to maintaining trust and adhering to regulatory requirements.

In future perspective new trends of BI are:

- Natural Language Processing (NLP) and Conversational BI: NLP and conversational BI enable users to interact with data using natural language queries and voice commands. This trend simplifies data access and analysis, making BI more accessible to a broader range of users.[40]
- Augmented Analytics: Augmented analytics combines machine learning and natural language processing to automate data preparation, analysis, and insights generation. It enables business users to access and interpret data more easily, empowering them to make data-driven decisions without relying heavily on data analysts or data scientists.[41]
- Advanced Data Visualization: Data visualization techniques are becoming more sophisticated, allowing for interactive and immersive visual representations of data. Advanced visualizations, such as augmented reality (AR) and virtual

[40] Menninger, David.: *Natural Language Processing Enables Self-service Analytics & BI*. [online]. <https://davidmenninger.ventanaresearch.com/natural-language-processing-enables-self-service-analytics-bi>

[41] Alghamdi, A. Noorah. Al-Baity, H. Heyam.: *Augmented Analytics Driven by AI: A Digital Transformation beyond Business Intelligence*. In: Sensors 2022. Vol. 22. Issue 20. [online]. < https://www.mdpi.com/1424-8220/22/20/8071>

reality (VR) dashboards, are emerging, providing users with more immersive and engaging experiences.[42]

- Artificial Intelligence (AI) and Machine Learning (ML) in BI: AI and ML technologies are being increasingly integrated into BI platforms. These technologies enhance data processing, automate data modelling and analysis, provide predictive and prescriptive insights, and enable intelligent data discovery.[43]

[42] Madhusudan, Rao. Dawarwadikar, Manoj.: *Immersive Visualizations Using Augmented Reality and Virtual Reality*. In: Lee, N. Encyclopedia of Computer Graphics and Games. Springer. 2020. p. 1-8

[43] Nishtha.: *Business Intelligence vs Artificial Intelligence-Battle of the Brains*. [online]. <https://www.projectpro.io/article/business-intelligence-vs-artificial-intelligence/788>

2. CHAPTER: BI ARCHITECTURE

A business intelligence (BI) architecture refers to the overall design and structure of the systems and components that enable a company to perform business intelligence and analytics. It articulates the technology standards, data management practices, and analytics practices that support an organization's BI efforts, as well as the specific platforms and tools that will be implemented. It serves as a technology roadmap for collecting, organizing, and managing BI data and making it available for analysis, data visualization, and reporting. Proper BI architecture also includes the principles that govern the use of the technology components (which we will cover at the end of the chapter).[44] Establishing such an architecture enables the BI team to work in a coordinated and disciplined manner to create an enterprise BI program that meets the organization's data analysis needs. The BI architecture also helps BI managers and data managers create an efficient process for managing and processing the data that is delivered to the environment. An effective BI architecture benefits companies as they use the information generated by business intelligence applications to make data-driven decisions that improve the company's performances. To ensure that their needs are met, executives, business managers, and other users who rely on data analytics to formulate strategies and make decisions should be involved in creating the architecture.[45]

The picture below shows one example of a generic BI architecture, we can divide the process underlying the BI architecture in basically five stages, starting from back-end operations, and ending to the front-end operations: data collection, data integration,

[44] Effah, John. Senyo, Kwame Prince. Opoku-Anokye, Stephen.: *Business Intelligence Architecture Informed by Organisational Semiotics*. 18th International Conference on Informatics and Semiotics in Organisations (ICISO), pp.268-277

[45] Indeed.: *What Is Business Intelligence Architecture? (With Benefits)*. [online]. <https://www.indeed.com/career-advice/career-development/business-intelligence-architecture>

data storage, data analysis, data distribution (in an equivalent framework of the stages, data warehouse includes data integration, data storage and data analysis).[46]

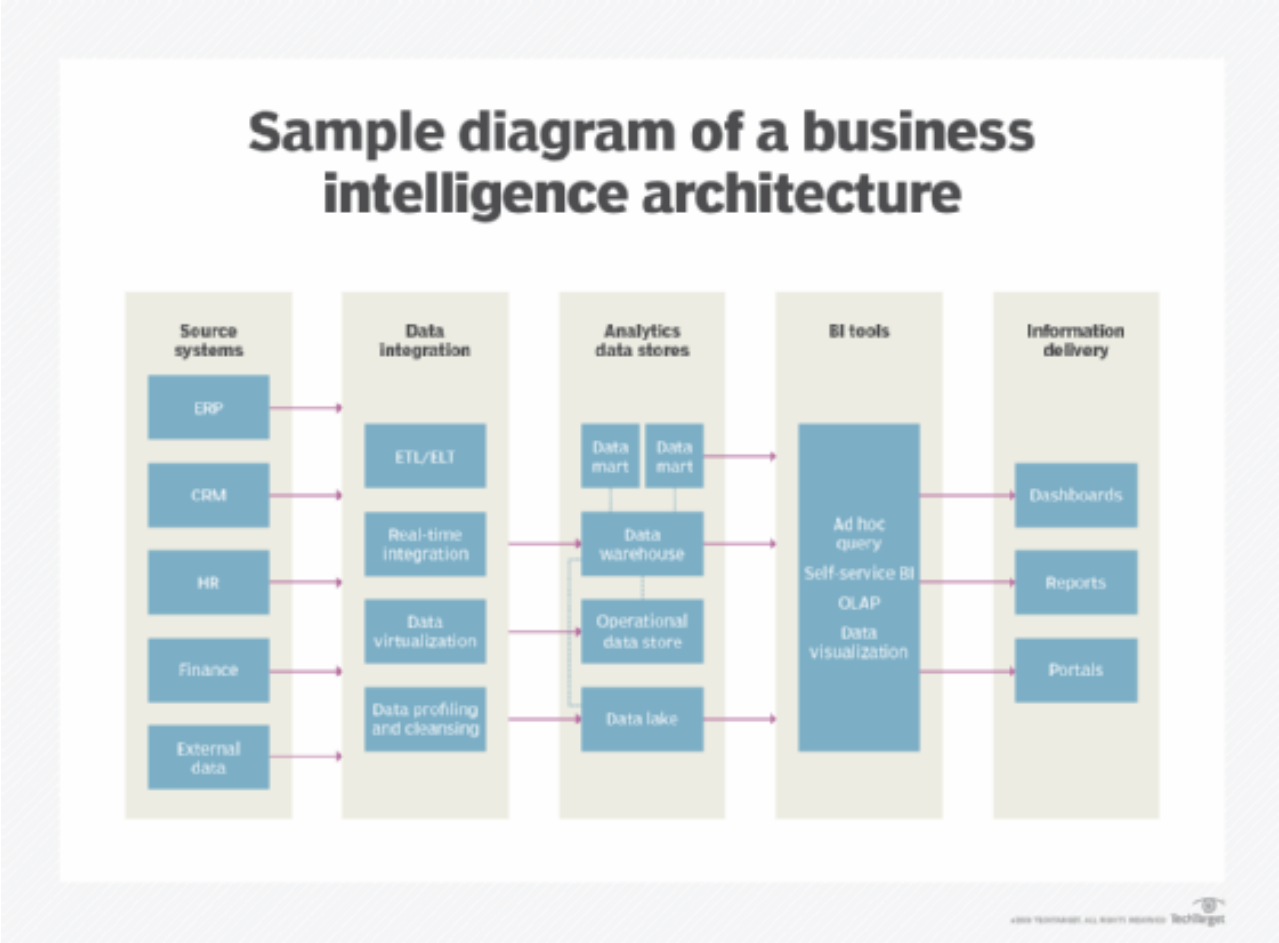

Figure 2.1 Sample diagram of a BI architecture

2.1) **Source systems**

These are all the systems that capture and store all the transactional and operational data identified as essential for the enterprise BI program, for example, ERP, CRM, finance, manufacturing, supply chain management systems; but also, general databases, files, or APIs, depending on the objectives and resources of the company. They can also include external sources, such as market data and customer databases

[46] Koberko, Tatyana.: *Business intelligence architecture: key components, benefits, and BI team*. [online]. <https://www.itransition.com/business-intelligence/architecture>

from outside information providers. As a result, both internal and external data sources are often incorporated into the DWH.[47]

In many cases, data sources come from different applications using software based on different technologies, for example, relational databases (Microsoft SQL Server, Oracle, MySQL, Microsoft Excel) and non-relational databases (txt, csv, xml). When this big amount of data is accumulated from different sources, the risk of discrepancies, errors and inconsistencies is high. For this reason, companies set different selection criteria during the data source selection process. A general rule that we can apply in almost all the cases is the "ten dimensions of data quality", this rule states some basics requirements a data should satisfy in order to be selected for the successive aggregation:

- Accuracy: refers to the correctness and precision of data.

- Completeness: measures the extent to which data captures all the required information.

- Consistency: ensures that data values are harmonized and conform to predefined rules and standards across different sources, systems, and timeframes.

- Timeliness: focuses on the relevance and currency of data (reflects the most recent information).

- Validity: examines whether data conforms to predefined rules, formats, and constraints.

[47] Pratt, K. Mary.: *business intelligence architecture*. [online].
<https://www.techtarget.com/searchbusinessanalytics/definition/business-intelligence-architecture>

- Integrity: data integrity ensures data remains intact and consistent over time, without unauthorized modifications or corruption.

- Uniqueness: measures the absence of duplicate or redundant data records.

- Precision: precise data provides sufficient specificity and granularity for the intended analysis or application.

- Relevance: assesses the significance and applicability of data to the intended purpose.

- Understandability: data is well-documented, labelled, and presented in a clear and intuitive manner.[48]

In addition, a combination of structured, data that is organized and formatted according to a predefined schema or model, unstructured, data that lacks a predefined structure or format, and semi-structured, data that is partially organized, containing both structured and unstructured elements, may be required to meet the data analysis and decision-making needs of executives and other business users.

2.2) **Data integration and cleansing tools**

Data integration and cleansing tools play a crucial role in the process of preparing data for analysis and reporting, to effectively analyse the data collected for a BI program, an organization must integrate and consolidate different data sets to create unified views of them, in order to do this, companies make use of various tools. These tools facilitate the extraction, transformation, and loading of data from the various sources

[48] David T. Bourgeois, Ph.D.; James l. Smith, Ph.D.; Shouhong wang, Ph.D. Joseph Mortati.: *Information Systems for Business and Beyond.* MBA. (2019). [online]. <https://opentextbook.site/informationsystems2019/>

to one unified and complete, of all the information needed, to the DWH, as well as the cleansing and standardization of data to ensure its quality and consistency.[49]

2.2.1) ETL

The most widely used data integration technology for BI applications is extract, transform and load (ETL) software, which pulls data from source systems in batch processes and load them to the DWH, in order to do so the data must be able to travel freely between systems and apps.[50]

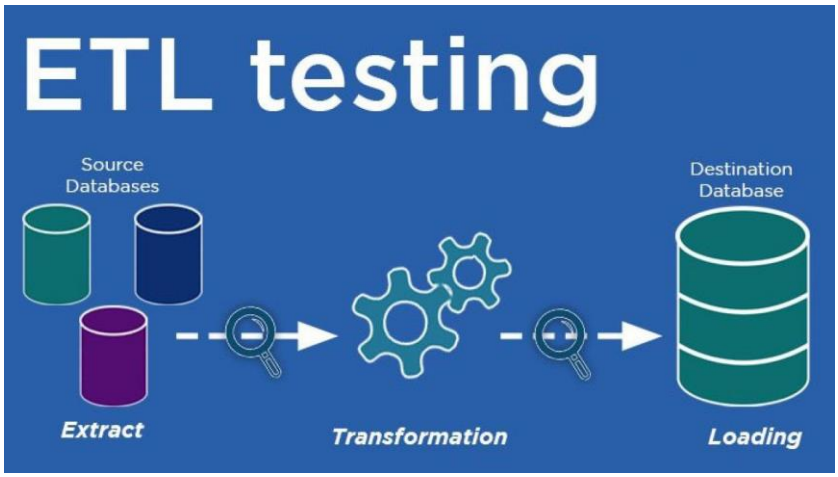

Figure 2. 2 Graphic representation of a ETL process

Extraction

In this phase, data is extracted from heterogeneous operating systems. The main objective of the process is to extract only the data of interest using as few resources as possible, in order to omit sets that are not purely relevant. In most cases, the process is executed in the background or at off-peak times, such as at night. This is so as not to affect the performance of the production systems. Extraction can be:

[49] Talend.: *What is Data Integration?* [online]. <https://www.talend.com/resources/what-is-data-integration/>
[50] IMB.: *What is ETL?* [online]. <https://www.ibm.com/topics/etl>

- static, which represents a snapshot of the information contained in the operational sources and is usually performed for the first Datawarehouse population.
- or incremental, where information from previous extractions is retained and only those records that have changed since the last extraction are updated.[51]

Transformation

Transformation is generally considered to be the most important part of the ETL process. Although the data management of a company impose different rules for the data conformity, the different sources store information in different formats, consequently, to carry out integration it is necessary to transform data into a uniform format. Series of transformations are applied to convert the data different format of the sources to one target format.[52] While the extract and load parts are rather mechanical, the transformation stage is a complex activity, which involves:

- Data profiling, process of analysing and assessing the structure, content, and quality of a dataset. It involves examining the characteristics, patterns, and statistics of the data to gain a better understanding of its properties and uncover potential issues or anomalies.[53] The objective is to provide insights into the dataset's overall quality, completeness, consistency, and adherence to predefined rules or constraints to define what kind of transformations are reasonable.[54]
- Data mapping, process of establishing relationships and mappings between data elements or attributes from different data sources or systems. It involves

[51] Eteng, Ofem.: *What is Data Extraction? Everything You Need to Know*. [online]. <https://hevodata.com/learn/data-extraction/>
[52] Talend.: *What is ETL?* [online]. <https://www.talend.com/resources/what-is-etl/>
[53] Panoply.: *What Is Data Profiling? Process, Best Practices and Tools*. [online]. <https://panoply.io/analytics-stack-guide/data-profiling-best-practices/>
[54] Talend.: *What is Data Profiling? Tools and Examples*. [online]. <https://www.talend.com/resources/what-is-data-profiling/>

identifying corresponding data fields, defining transformation rules, and aligning data structures to ensure compatibility and consistency during data integration or migration processes. Data mapping helps in understanding how data flows and is transformed from the source to the target system.[55]

- Code Creation and Actual Execution: Code creation refers to the development of software code or scripts that implement specific tasks or functionalities defined during the data mapping. Once the code is created, it can be executed to perform the desired operations on the data.
- Data audit is a systematic examination and evaluation of data to assess its quality, accuracy, and adherence to standards, regulations, or business requirements after the transformation. It involves conducting thorough reviews of data sources, data processes, data handling procedures, and data management practices. The objective is to identify and mitigate risks, ensure data integrity, validate data compliance, and maintain data governance and security standards. A data audit may involve reviewing data documentation, data access controls, data usage patterns, and data protection mechanisms. It helps in identifying data issues, potential vulnerabilities, and areas for improvement in data management practices.

The exact transformations (which are multiple) are defined according to the purpose that the data will serve and by specific business rules set by the company that is adopting it.[56] Examples of transformation are:

- Aggregation of several columns into a single one, or vice versa, the split of a column into several ones.
- Encodement of values or translation of the existing ones (‘New York’ to ‘NY’, ‘Turin’ to ‘TO’, or ‘1’ to ‘Female’, ‘2’ to ‘Male’, these are specific

[55] Talend.: *What is Data Mapping?*. [online]. <https://www.talend.com/resources/data-mapping/>
[56] Korobeyko, Tatyana.: *Business intelligence architecture: key components, benefits, and BI team.* [online]. <https://www.itransition.com/business-intelligence/architecture>

codifications that companies/countries adopt according to their needs/previous usage).

- Creation of new calculations or derivation of new attributes out of the existing ones (for example, to follow varying accounting rules, i.e., revenue starting from quantities sold and prices).
- Conversion of low-level data attributes into high level-attributes, and many others.[57]

In general data transformation improves data integrity by removing duplicates and ensuring that raw data arrives at its new destination fully compatible and ready to use.

Loading

The last step of the ETL process is to load the newly transformed data into a new destination. The data can be loaded all at once (full load) or at regular intervals (incremental load).[58]

- Full Load, in a full load ETL scenario, everything in the conversion chain is transformed into new, unique records in the data store or data warehouse. While in some cases this is useful for search purposes, full loads produce datasets that grow exponentially and can quickly become difficult to maintain.
- Incremental loading, incremental loading is a less comprehensive but more manageable approach. With incremental loading, incoming data is compared to what is already available and additional records are created only if new and unique information is found. This architecture allows smaller and less expensive data warehouses to be maintained and managed.[59]

[57] Korobeyko, Tatyana.: *Business intelligence architecture: key components, benefits, and BI team.* [online]. <https://www.itransition.com/business-intelligence/architecture>
[58] Gemes, Nikola.: *ETL Data Transformation Process: The Step-By-Step Guide.* [online]. <https://whatagraph.com/blog/articles/etl-data-transformation>
[59] Dave Brijesh.: *What, Why & How — Data Warehouse and ETL*. [online]. <https://medium.com/intellyticssolutions/what-why-how-data-warehouse-and-etl-9ebd198d36c7>

In some cases, the data are not directly loaded into the core of the warehouse, but first into the staging area. This is an area that allows the ET processing to be separated from the loading into the DWH, in this way more complex data cleaning and transformation can be performed, the disadvantages are the introduction of additional redundancy and an increase in the space required for data (the structure of a DWH will be discussed in the following section).[60]

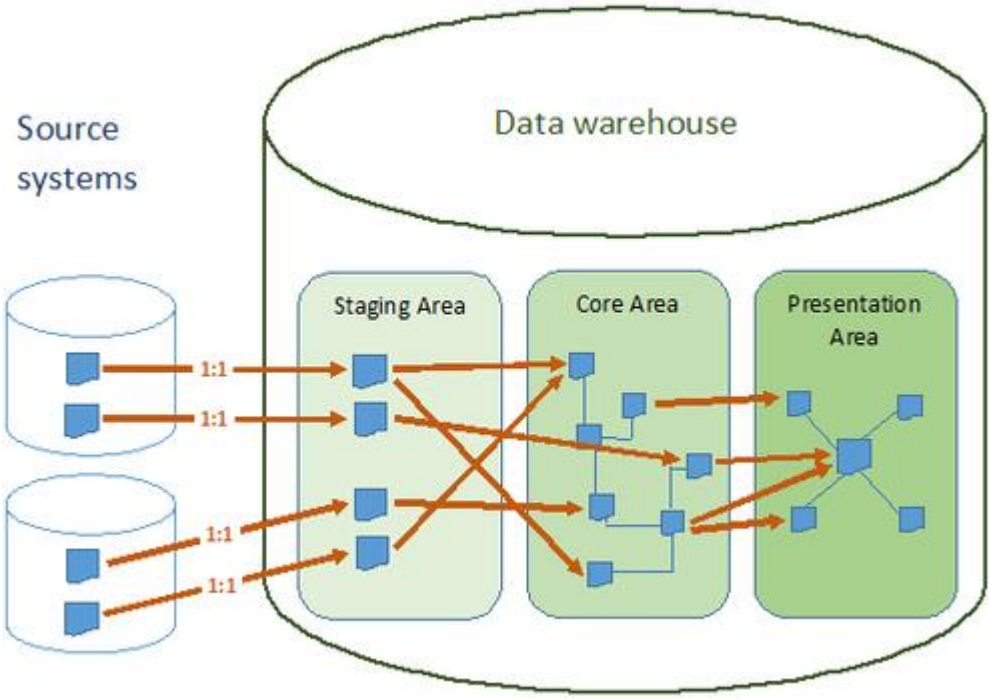

Figure 2. 3 Graphic representation of a ETL process with staging area

Popular ETL tools include Informatica PowerCenter, IBM InfoSphere DataStage, Microsoft SQL Server Integration Services (SSIS), and Talend.

2.2.2) ELT

ELT stands for Extract, Load, Transform. It is an alternative approach to data integration and processing compared to the traditional ETL (Extract, Transform, Load) approach. While ETL focuses on extracting data from various sources,

[60] Varshney, Hars.: *What is a Data Staging Area?* | Staging Data Simplified 101. [online]. <https://hevodata.com/learn/data-staging-area/>

transforming it, and then loading it into a target system, ELT reverses the order of the transformation and loading steps. In ELT, the data is first extracted from the source systems and loaded directly into the target data warehouse, without significant transformation. The transformation step is performed within the target system using powerful processing capabilities provided by the data storage platform, such as SQL queries, data manipulation languages, or specialized data processing frameworks like Apache Spark. [61]

ELT is not a replacement for ETL but rather an alternative approach that suits certain use cases, especially those involving large volumes of data and more complex transformation requirements. The choice between ETL and ELT depends on factors such as data volume, data complexity, performance requirements, and the capabilities of the target data storage platform. Other methods include real-time data integration, such as change data capture and streaming integration to support real-time analytics applications, and data virtualization, which combines data from different source systems virtually.

2.3) **Analytics data stores**

Analytics data store encompasses the various repositories where BI data is stored and managed. The most common is data warehouse. A data warehouse is a centralized repository that stores and manages large amounts of structured and semi-structured data, from various sources, in a relational, columnar or multidimensional database and makes it available for querying and analysis. The structure of a DW can vary significantly depending on the needs of the company adopting it.

BI and DWH are terms strictly related, data warehousing is the most important stage of the BI architecture, precisely because of this often they are considered

[61] Bartney, Kevin.: *ETL vs ELT: What´s the Difference?* [online]. <https://rivery.io/blog/etl-vs-elt/>

interchangeable concepts. But while DWH refers to the process of collecting, organizing, and storing large volumes of data to provide a centralized view, BI refers to a broader concept that includes processes, technologies, and tools used to gather, analyse, and present data in a meaningful way to support decision-making.[62]

2.3.1) Datawarehouse Structure

When designing a data warehouse, two common approaches are the bottom-up approach and the top-down approach:

- Bottom-Up Approach: The bottom-up approach, also known as the data mart approach, involves starting with individual data marts and then integrating them into a larger data warehouse. This approach emphasizes building smaller, specialized data marts that cater to specific business departments or functions. These data marts are designed to address the specific reporting and analysis needs of those departments.

  Advantages of the bottom-up approach include faster implementation, flexibility in accommodating changing business requirements, and the ability to address specific departmental needs effectively. However, it may result in data redundancy and may require additional effort to ensure consistency and integration across different data marts.

- Top-Down Approach: The top-down approach, also known as the enterprise data warehouse (EDW) approach, involves building a centralized data warehouse that serves as the single source of truth for the entire organization.

[62] Biere, Mike.: *Business Intelligence for the Enterprise*. Chapter 2. In: IBM Press. 2003. ISBN: 9780131413030.

This approach focuses on creating a comprehensive, integrated data model that covers the entire range of business processes and functions.

Advantages of the top-down approach include better data integration, improved data consistency, and the ability to support cross-functional analysis and reporting. However, it may involve a longer development timeline and may require more upfront planning and coordination across different departments.

Although the framework of a DW can vary greatly depending on the needs of the company building it, here we try to give a general idea of how it might be structured These approaches are classified by the number of tiers in the architecture.

Single-tier Data Warehouse Architecture:

The single-tier architecture is not a frequently practiced approach. The main goal of having such an architecture is to remove redundancy by minimizing the amount of data stored. From the other side the disadvantage is that it does not have a component that separates analytical and transactional processing.

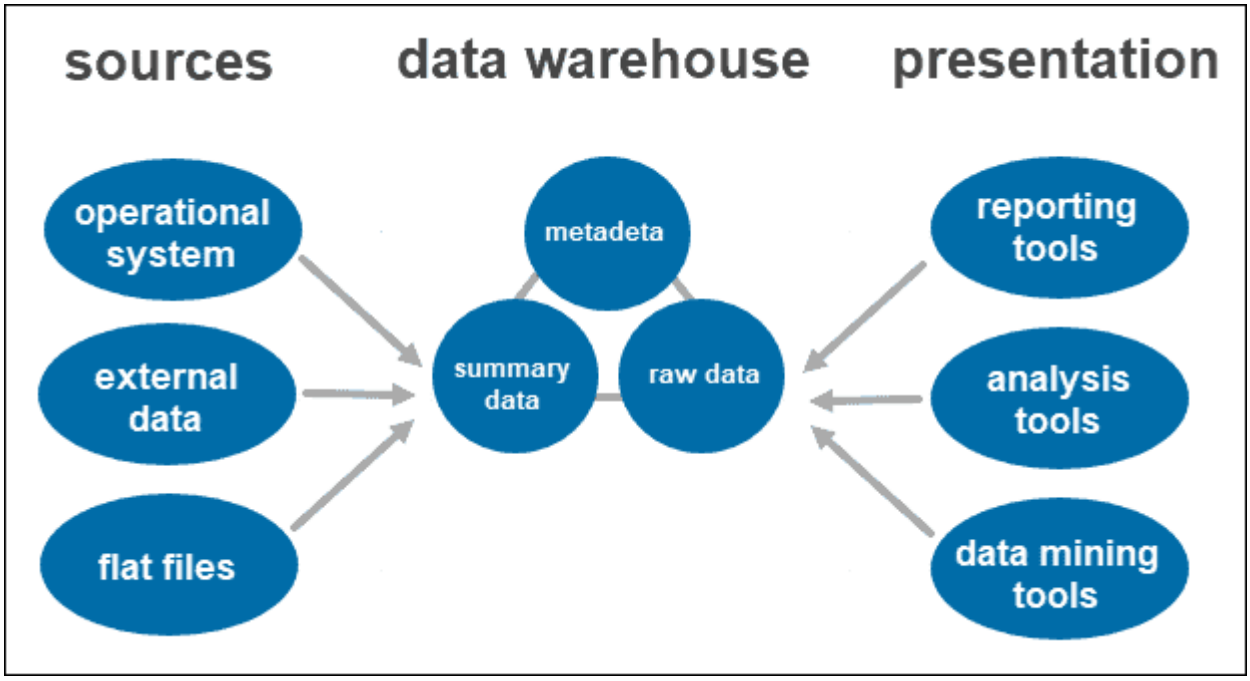

Figure 2. 4 Graphical representation of a Single-Tier DW structure

Two-tier Data Warehouse Architecture

A two-tier architecture includes a staging area for all data sources before the data warehouse layer. By adding a staging area between the sources and the storage repository, you ensure all data loaded into the warehouse is cleansed and in the appropriate format. This approach has certain network limitations, it is not possible to expand it to support a larger number of users.

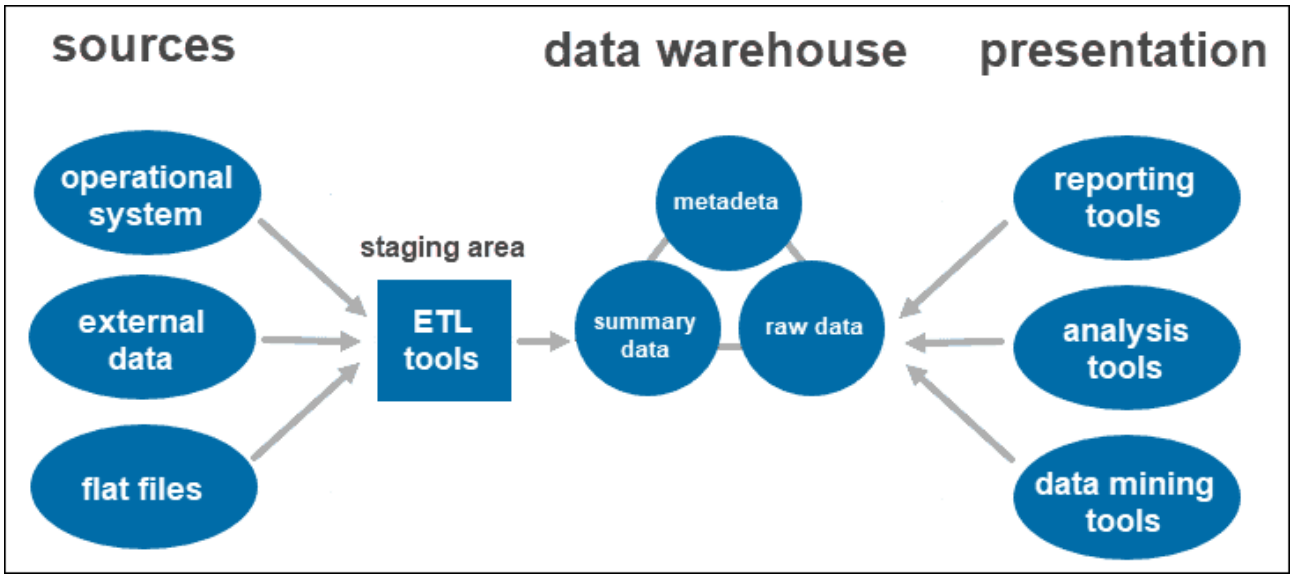

Figure 2. 5 Graphical representation of a Two-Tier DW structure

Three-tier Data Warehouse Architecture

The three-tier approach is the most widely used architecture for data warehouse systems. The tiers are divided as follows:

- The bottom tier is the database of the warehouse, where the cleansed and transformed data is loaded.
- The middle tier is the application layer giving an abstracted view of the database. It arranges the data to make it more suitable for analysis. This is done through the OLAP system.

- The top-tier is where the user accesses and interacts with the data. It represents the front-end client layer. You can use reporting tools, query, analysis, or data mining tools.

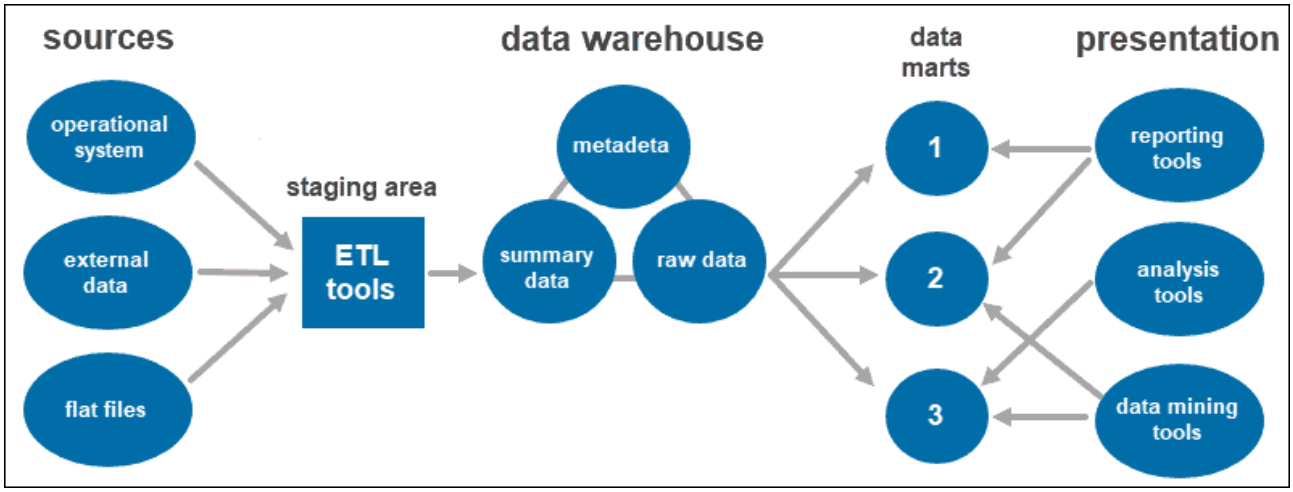

Figure 2. 6 Graphical representation of a Three-Tier DW structure

2.3.2) Databases

All business information systems and applications rely on databases to collect, store, process, and analyse any data relevant to the business. They are the most generic form of data repository. There are different types of databases, it is possible to divide them, by the purpose they serve in a company, in transactional or operational, and analytical databases. The former is used for collecting and storing all the data coming from the company's daily business operations; each company may have several transactional databases depending on how many software applications the company has, to track its business processes. The latter is used to analyse this information and to get insight from them. In this case a second space is designed, where the most relevant data, coming from operational databases, is transferred, and updated periodically, these are the analytical databases. The structure of the company databases will be divided in two levels: to allow for operational-type processing on the one hand, and analytical-type processing on the other.

Transactional databases

Transactional databases, also known as operational systems, are designed to facilitate and manage day-to-day business operations. These systems handle business transactions, capture and store operational data, and support core business processes. Since they are used for strictly practical activities, the most important aspects are data integrity and consistency constraints to ensure the accuracy and reliability of data. In order to ensure the right coverage of these aspects, techniques such as ACID are used to ensure that transactions are handled in a controlled and predictable manner, allowing businesses to maintain data integrity and recover from failures effectively. ACID is an acronym that stands for Atomicity, Consistency, Isolation, and Durability. These are a set of properties that ensure reliable and consistent transaction processing in a database system.

- Atomicity guarantees that a transaction is treated as a single indivisible unit of work. It ensures that either all the operations within a transaction are successfully completed and committed, or none of them are. If any part of the transaction fails, the entire transaction is rolled back, and the database is left unchanged.
- Consistency ensures that a transaction brings the database from one valid state to another by enforcing integrity constraints, data validation rules, and business rules defined on the database. Transactions should maintain data integrity and enforce the consistency of the database by preserving all defined relationships and constraints.
- Isolation: Isolation ensures that concurrent transactions do not interfere with each other. Each transaction operates in isolation, as if it were the only transaction being executed. Isolation prevents dirty reads, non-repeatable reads, and phantom reads. It ensures that the intermediate states of a transaction are not visible to other transactions until it is committed.
- Durability: Durability guarantees that once a transaction is committed, its changes are permanent and will survive any subsequent failures, such as power

outages or system crashes. The changes made by a committed transaction are stored in a durable storage medium, typically disk, to ensure data persistence and recovery.

In order to manage and process high volumes of transactions in real-time also other applications are needed, databases together with these related applications form OLTP system. OLTP (Online Transaction Processing) refers to a class of database systems and applications that are designed to manage and process high volumes of transactions in real-time. They are used in operational environments (such as: POS, banking, E-commerce, stock trading, …), where transactions occur frequently, because of the extremely short response time.

Analytical databases

Analytical databases, on the other hand, are focused on data analysis, reporting, and decision support. These systems enable users to extract meaningful insights from data, identify patterns, perform aggregations, and gain a deeper understanding of business performance. Analytical databases aggregate data from multiple transactional databases and other data sources into a centralized data repository. Data warehouse is one example of analytical database.[63]

2.3.3) Data Marts and Data Lake

Data warehouse is the most common used data repository to support a BI, but there are alternative possible solutions such as data lake and data marts.

Data lake is a centralized repository that stores large volumes of raw, unprocessed, and diverse data in their native format with no need of transformation to pre-defined or structured data model. The main difference from data warehouse is, properly this,

[63] Korobeyko, Tatyana.: *Business intelligence architecture: key components, benefits, and BI team.* [online]. <https://www.itransition.com/business-intelligence/architecture>

a data lake can store vast amounts of data in its original, untransformed state, providing flexibility in incorporating new data sources, in this way is possible to skip the ETL stage (or every alternative stage of transformation).[64] It is important to note that data lakes can also introduce challenges related to data quality, data governance, and data management. Even if they can accommodate a wide variety of data types, formats, and sources data lakes are still highly scalable. Organizations need to implement appropriate data lake architectures, metadata management strategies, and data governance practices to ensure the effectiveness and usability of the data lake environment. A data lake can also be incorporated into a BI architecture as a repository for raw data of various types. The data can be analysed in the data lake itself or filtered and loaded into a data warehouse for analysis. A well-planned architecture should specify which of the different data stores is best suited for particular BI uses.[65]

Instead, Data marts are subsets of a data warehouse that focus on specific business functions or departments within an organization, sometimes it become even more useful if the departments of the organization are localized in different geographical areas. They are smaller data repositories that contain data relevant to a particular area of the business. This makes them provide faster query response compared to querying the entire data warehouse and also, they can be developed, updated, and modified more quickly.[66] There are different approaches to implementing data marts.

- Independent Data Marts: Each data mart is created and maintained separately, catering to the specific needs of a department or business area. They may have their own ETL (Extract, Transform, Load) processes and data storage.
- Dependent Data Marts: Data marts are derived from a central data warehouse, leveraging the existing data integration processes and infrastructure. They are

[64] Domo.: *What is business intelligence architecture?* [online]. < https://www.domo.com/learn/article/what-is-business-intelligence-architecture>
[65] Ranjan, Jayanthi.: *BUSINESS INTELLIGENCE: CONCEPTS, COMPONENTS, TECHNIQUES AND BENEFITS*. [online]. < http://www.jatit.org/volumes/Vol9No1/9Vol9No1.pdf>
[66] Biere, Mike.: *Business Intelligence for the Enterprise*. Chapter 7. In: IBM Press. 2003. ISBN: 9780131413030.

created by filtering and aggregating data from the data warehouse to meet the requirements of specific business areas.[67]

BI architecture is really important because as we saw there are many possible solutions that can be created combining all the components that we saw. The perfect BI architecture does not exist, but knowing the company's framework and needs it is possible to combine the right components and find the optimal solution for the specific case.

2.4) **BI and data visualization tools**

The tools used to analyse data and present information to business users include a suite of technologies that can be built into a BI architecture, for example, ad hoc query, data mining and online analytical processing, or OLAP software. In addition, the growing adoption of self-service BI tools enables business analysts and managers to run queries themselves instead of relying on the members of a BI team to do that for them.

2.4.1) OLAP Systems

OLAP is a database technology that has been optimized for querying and reporting, instead of processing transactions. While OLTP systems are transaction-oriented, with an emphasis on data integrity and concurrency control; OLAP systems are designed for analytical processing, enabling multidimensional analysis, and providing insights from summarized and historical data. The source data for OLAP are commonly analytical databases, mostly warehouses.[68] The peculiarity that makes this

[67] IBM: *Data Mart Consolidation: Getting Control of Your Enterprise Information*. [online]. <https://redbooks.ibm.com/redbooks/pdfs/sg246653.pdf>
[68] Ranjan, Jayanthi.: *BUSINESS INTELLIGENCE: CONCEPTS, COMPONENTS, TECHNIQUES AND BENEFITS*. [online]. < http://www.jatit.org/volumes/Vol9No1/9Vol9No1.pdf>

technology special is that data are organized hierarchically and stored in cubes instead of tables. Using this multidimensional structure is possible to provide rapid access to data for analysis. The OLAP cube extends the single table with additional layers, each adding additional dimensions.[69] For example, the top layer of the cube might organize sales by region; additional layers could be country, then state, and so on with region, city and even specific store. In theory, a cube can contain an infinite number of layers (an OLAP cube representing more than three dimensions is sometimes called a hypercube). Also, smaller cubes can exist within layers, for example, each store layer could contain cubes arranging sales by salesperson and product. In practice, data analysts will create OLAP cubes containing just the layers they need, for optimal analysis and performance.[70] There are different operations that OLAP performs, and each accomplishes different analytical tasks that businesses use to retrieve data:

- Slice: The slice operation involves selecting a specific subset of data by fixing the values of one or more dimensions. It allows users to view a slice of the data cube that corresponds to a particular combination of dimension members. For example, selecting sales data for a specific product category and time period.
- Dice: dice operation extends the slice operation by selecting a subset of data based on multiple dimension values. It allows users to define a custom subset of the data cube by specifying values for multiple dimensions simultaneously. For example, selecting sales data for a specific product category, region, and time period.
- Drill Down; involves navigating from a higher-level summary to a lower-level detail. It allows users to explore the data cube at a more granular level by expanding the view. For example, starting with annual sales figures and drilling down to quarterly, monthly, and daily levels.

[69] Golfarelli, Matteo.: *New Trends in Business Intelligence*. [online]. <http://bias.csr.unibo.it/golfarelli/Papers/BIS05.pdf>
[70] In Lih Ong, Pei Hwa Siew, Siew Fan Wong.: *A Five-Layered Business Intelligence Architecture*. [online]. <https://ibimapublishing.com/articles/CIBIMA/2011/695619/695619.pdf>

- Roll-up: it is the inverse of drill down. It involves aggregating data from a lower-level detail to a higher-level summary. By rolling up the data, users can view the data cube at a higher level of aggregation. For example, rolling up daily sales data to monthly or yearly totals.
- Pivot: allows users to reorient the axes of the data cube to gain different perspectives on the data. It involves rotating or reorganizing the dimensions to analyse data from various angles. For example, pivoting a sales cube to analyse sales figures by product category along one axis and by region along another axis.
- Drill Across: enables users to navigate across different dimensions of the data cube. It involves accessing related data from other cubes or data sources to perform comparative analysis. For example, drilling across from sales data to customer data to analyse sales performance by customer segment.[71]

OLAP that works directly with a multidimensional OLAP cube is known as multidimensional OLAP, or MOLAP. For most uses, MOLAP is the fastest and most practical type of multidimensional data analysis. However, there are two other types of OLAP which may be preferable in certain cases:

- ROLAP or relational OLAP, is multidimensional data analysis that operates directly on data on relational tables, without first reorganizing the data into a cube. As noted previously, SQL is a perfectly capable tool for multidimensional queries, reporting, and analysis. But the SQL queries required are complex, performance can drag, and the resulting view of the data is static—it can't be pivoted to represent a different view of the data. ROLAP is best when the ability to work directly with large amounts of data is more important than performance and flexibility.
- HOLAP, or hybrid OLAP, attempts to create the optimal division of labor between relational and multidimensional databases within a single OLAP

[71] Java Point.: *OLAP Operations in the Multidimensional Data Model*. [online]. <https://www.javatpoint.com/olap-operations>

architecture. The relational tables contain larger quantities of data, and OLAP cubes are used for aggregations and speculative processing. HOLAP requires an OLAP server that supports both MOLAP and ROLAP. A HOLAP tool can "drill through" the data cube to the relational tables, which paves the way for quick data processing and flexible access. This hybrid system can offer better scalability but can't escape the inevitable slow-down when accessing relational data sources. Also, its complex architecture typically requires more frequent updates and maintenance, as it must store and process all the data from relational databases and multidimensional databases. For this reason, HOLAP can end up being more expensive. [72]

2.5) **Dashboards, portals, and reports**

BI software also includes data visualization tools that can be used to create graphical representations of data, in the form of charts, graphs and other types of visualizations designed to illustrate trends, patterns and outlier elements in data sets. These information delivery tools give business users visibility into the results of BI and analytics applications, with built-in data visualizations and, often, self-service capabilities to do additional data analysis. For example, BI dashboards and online portals can both be designed to provide real-time data access with configurable views and the ability to drill down into data. Reports tend to present data in a more static format.

Other components that increasingly are part of a business architecture include data preparation software used to structure and organize data for analysis and a metadata

[72] Taylor David.: *What is OLAP? Cube, Analytical Operations in Data Warehouse*. [online]. <https://www.guru99.com/online-analytical-processing.html>

repository, a business glossary and a data catalogue, which can all help users find relevant data and understand its lineage and meaning.

2.6) **Data Governance and Data Management**

As we have seen so far, data play an essential role and is at the heart in the various BI processes. Moreover, the amount of data that a company produces and manages nowadays is almost unquantifiable. Precisely because of this, companies have begun to pay more and more attention to how this data is managed, in order to avoid running into the various problems that mismanagement of this data could provoke. Data governance and data management are concepts designed to deal with this issue, with the former dealing with generating shared rules inside a company to effective handle and utilize data within an organization and the latter dealing with finding ways to make them enforceable.

2.6.1) Data governance

Data governance is the framework and set of processes that organizations establish to ensure the effective and efficient management of their data assets. The primary goal is to ensure that data is accurate, consistent, accessible, secure, and aligned with business objectives.[73] In larger companies, real data governance committees are established, their job is to issue policies outlining the principles, rules, and guidelines that govern the management and the use of data. These policies cover various aspects such as:

- Data Stewardship: involves assigning ownership, responsibility, and accountability for specific data assets to individuals or teams within the organization. Data stewards are responsible for managing and maintaining the quality, integrity, and usability of the data. They enforce data governance

[73] Satori.: *Guide: Data Governance.* [online]. < https://satoricyber.com/data-governance/essential-guide/>

policies, oversee data-related processes, and act as advocates for data quality and governance within their respective domains.[74]

- Data Standards: data standards define the rules and conventions for data management, including data naming conventions, data formats, data definitions, and data classifications. Standards ensure consistency, interoperability, and understanding of data across the organization. They enable effective data integration, data sharing, and data analysis.

- Data Privacy and Security, it addresses the protection of sensitive and confidential data through the establishment of data privacy and security measures. This includes defining access controls, implementing data encryption, establishing data masking techniques, and ensuring compliance with data protection regulations such as GDPR (General Data Protection Regulation).

- Compliance and Regulatory Alignment: Data governance ensures that the organization's data-related practices align with relevant regulations, industry standards, and best practices. It helps organizations demonstrate compliance with data protection laws, financial regulations, or industry-specific requirements.

- Data Governance Communication and Training: Effective data governance requires clear communication and training programs to ensure that employees understand their roles, responsibilities, and the importance of data governance. Training helps promote a data-driven culture within the organization and ensures that data governance practices are consistently implemented.[75]

[74] Frenté, Shauna.: *Data Governance Framework: 5 Key Elements.* [online]. <https://www.dataversity.net/5-key-elements-of-a-data-governance-framework/>
[75] Satori.: *Guide: Data Governance*. [online]. < https://satoricyber.com/data-governance/essential-guide/>

2.6.2) Data Management

Data management is aligned with data governance principles and policies, its activities adhere to established data governance frameworks, guidelines, and standards. Data governance provides the overarching framework for data management practices, including data quality, data security, data privacy, and compliance.[76] Data management covers all the activities regarding data through different dedicated software, in addition to those already mentioned in this chapter, other topics that data management deal are:

- Data Quality Management: data quality tools help identify and resolve data quality issues, such as missing values, inconsistencies, duplicates, and incorrect formatting. These tools provide capabilities for data profiling, cleansing, standardization, and enrichment.[77]

- Metadata Management: Metadata refers to the information that describes the characteristics, properties, and context of data. Metadata management involves capturing, organizing, and maintaining metadata to enable better understanding, discovery, and governance of data assets. It includes metadata standards, metadata repositories, data dictionaries, and metadata documentation.[78]

- Data Lifecycle Management: Data management encompasses the entire lifecycle of data, from creation or acquisition to archival or deletion. It includes defining data retention policies, managing data backups, implementing data

[76] Vancauwenbergh, Sadia.: *Data Quality Management*. In: IntechOpen. Scientometrics Recent Advances. p. 1-15
[77] Vancauwenbergh, Sadia.: *Data Quality Management*. In: IntechOpen. Scientometrics Recent Advances. p. 1-15
[78] TIBC.: *What is Metadata Management? [online]. <https://www.tibco.com/reference-center/what-is-metadata-management>*

archival strategies, and ensuring compliant disposal of data when no longer needed.[79]

- Data Catalogues: Data catalogues provide a centralized repository to document and organize metadata about data sources, data models, and data transformation processes. They enable users to discover, understand, and govern data assets across the organization.[80]

[79] IBM.: *What is data lifecycle management?* [online]. <https://www.ibm.com/topics/data-lifecycle-management>
[80] Wells, Dave.: *What Is a Data Catalog? Data Catalog Features & Benefits*. [online]. <https://www.alation.com/blog/what-is-a-data-catalog/>

CHAPTER 3: BUSINESS INTELLIGENCE APPLICATIONS

In the previous chapter, BI architecture, we focused on the various data flows. All the operations seen so far took place in the back-end, not visible to the final users. The flow begins with the extraction of data from the various internal or external repositories used by the company, then, through successive steps, it arrives at the final stage of data visualisation, where it becomes available for the final users. An enormous amount of data has been collected so far and deposited in a unique data warehouse (or in general in a database) in order to be used for BI purposes. These data, although classified and catalogued according to precise rules, are not ready for end users yet. The objective now will be to show how this data will be exposed to users in a clear manner according to given patterns and trends in order to create the conditions to extract insight from them, providing a basis for decision-making and company strategies. If until now problem and solutions could be analysed from a more technical point of view, from now on, issues will be addressed in a more functional way by combining IT skills with more functional skills depending by the area BI is supposed to support. Close collaboration between developers and users, who will use BI, is mandatory, and the focus from now on will be on front-end side. With ever-increasing technological advancements, there are many BI applications in today's world that are further specialized in different kinds of data analysis according to the needs of the company. In the following sections will list some of the areas where BI finds application and some of the most used BI tools, in the second part the platform QlikView of Qlik will be presented.

3.1) Sales Intelligence

The relationship with customers is an aspect that must be considered for a company that wants to be successful. Customer behavior is not an immediately predictable variable, but with a structured analysis it is possible to derive useful information to approach new or existing customers. Sales Intelligence is a subset of BI specifically focused on providing insights and analysis related to sales activities. The main sources used, in the Sales Intelligence platforms of BI, to collect and integrate data are all the database software related somehow with the "consumers relation" field, such as CRM systems, marketing automation tools, social media, and external databases.[81]

The data collected can be customers age or demographics, market penetration, lifetime value, conversion rates, and so on. Then they are organized in various forms (graphs, charts, …) to be easily understandable by the users. Thanks to the application the sales process becomes smoother and more predictable. Analyzing historical data and using predictive analytics, the management can forecast future demand or uncover unknown patterns, trends, and correlations. In this way is also possible to identify sales opportunities and forecast future outcomes to have a clear picture of what is the situation and enable data-driven decisions that can be setting realistic sales targets, allocate resources effectively, and plan inventory levels. Other benefits come from using demographics, purchase history, preferences, and behavior information. Companies can define really accurate customers segmentation models, and this helps in tailoring sales strategies, targeted marketing campaigns, and personalized customer experiences.[82]

Sales Intelligence provides insights into competitors' sales strategies, pricing, product positioning, and market share. And it helps businesses identify their strengths and

[81] Sales Intelligence Blog.: *What is Sales Intelligence and How Does it Help Your Sales Success?.* [online].<https://www.echobot.com/sales-blog/b2b-sales/sales-intelligence-for-sales-success/>
[82] Bergen, Adair.: *Business Intelligence Applications: Understanding the Application of BI*. [online]. <https://www.selecthub.com/business-intelligence/4-key-bi-applications/>

weaknesses compared to competitors and make informed decisions to gain a competitive advantage.

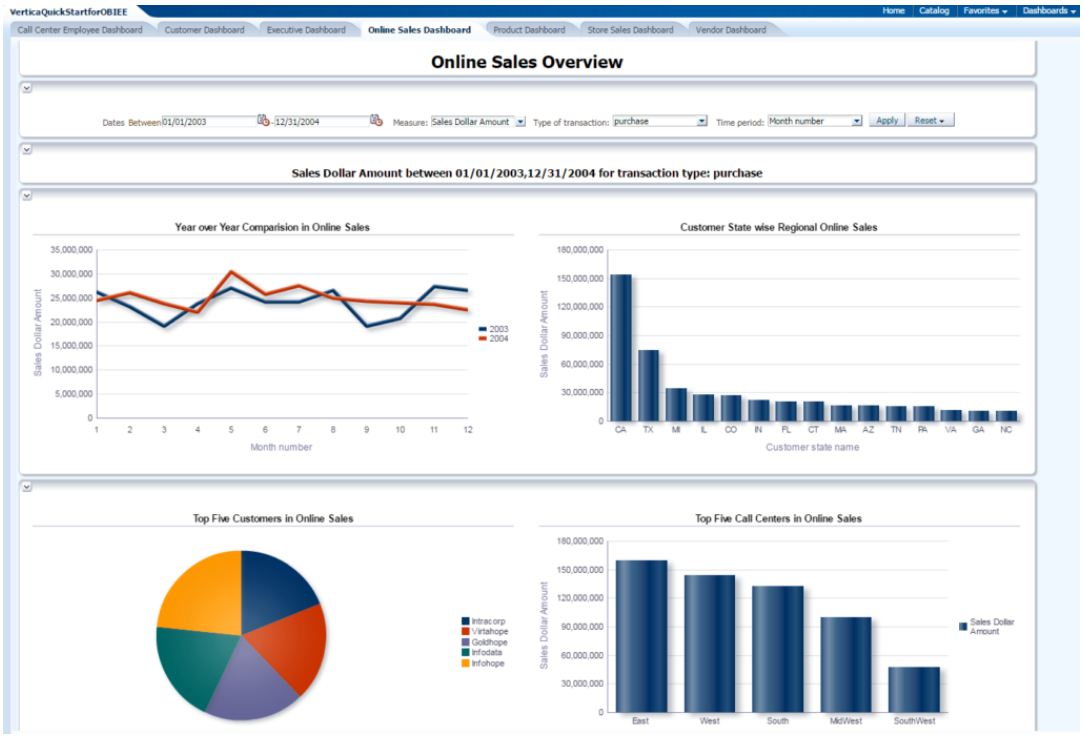

Figure 3.1 Dashboard from Oracle. It provides an overview of the company's sales. It is an example of how a BI application has organized various data and presented them so that any user can understand them and be able to evaluate a decision from them.

Sales is one of the fields where this technology becomes really efficient every company gets a great advantage from it, especially in highly competitive industries. A combination between Customer relationship management (CRM) software and Sales Intelligence platforms offers companies an advanced method to know customers' needs and make informed sales decisions.[83]

[83] Cognism.: *What is Sales Intelligence?*. [online]. <https://www.cognism.com/what-is-sales-intelligence>

3.2) Performance Management

Business intelligence (BI) in the context of performance management involves the use of BI tools and techniques to measure, analyse, and optimize the performance of various aspects of an organization. It aims to align business goals, monitor key performance indicators (KPIs), and drive continuous improvement.[84]

The first step is setting clear and measurable data-driven goals aligned with the organization's overall strategy that can include project completion dates, delivery times, or sales targets. These goals can be defined at different levels, such as organizational, departmental, or individual, and should be specific, measurable, achievable, relevant, and time-bound (SMART), some BI systems also provide suggestions of reasonable goals or target delivery times to set based on previous performances.[85] The second step is to identify and select relevant KPIs that directly contribute to the achieving of the defined goals and that reflect the results of critical areas or processes within an organization, there may be different KPIs based on the industry, department, and specific objectives, such as sales revenue, customer satisfaction, employee productivity, or operational efficiency.[86] At this point performance management BI, analysing the data from the various sources, provide real-time or near-real-time monitoring of KPIs, allowing users to identify deviations, anomalies, or trends that require attention. Alerts and notifications can be set up to trigger when predefined thresholds or targets are exceeded or not met in order to make management aware of the situation in the shortest time possible.[87] When performance issues or deviations are detected, the platform facilitates root cause analysis to identify the underlying factors contributing to the problem. Data exploration and ad hoc

[84] Zdraveski, Dejan.: *Business intelligence application in performance management*. In: SM. 2009.
[85] Golfarelli, Matteo.: *New Trends in Business Intelligence*. [online].
<http://bias.csr.unibo.it/golfarelli/Papers/BIS05.pdf>
[86] Mind Tools Contenzt Team.: *Performance Management and KPIs*. [online].
<https://www.mindtools.com/aia3zkb/performance-management-and-kpis>
[87] Bergen, Adair.: *Business Intelligence Applications: Understanding the Application of BI*. [online].
<https://www.selecthub.com/business-intelligence/4-key-bi-applications/>

analysis help investigate relationships, dependencies, and correlations between different variables, enabling to pinpoint the causes of performance gaps.[88]

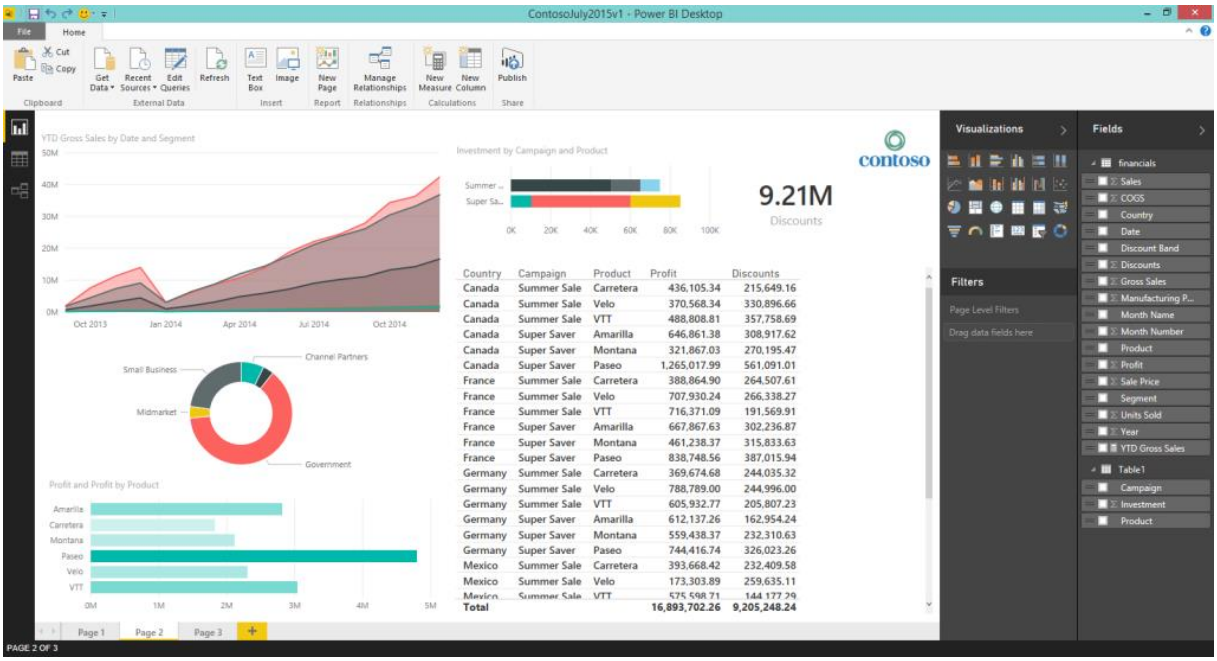

Figure 3.3 Example of an overview of performance management metrics from Microsoft Power BI

Organizations, in addition can identify areas for optimization, develop action plans, and track the impact of these initiatives on performance metrics, in this way is possible to monitor the effectiveness of the improvement efforts and provide feedback for ongoing adjustments and refinements.[89]

3.3) Visualization

Data Visualization for BI purposes is a more generic application compared to Sales Intelligence. Indeed, visualization tools can be applied to any possible field: logistic, finance, accounting, and many others, even as previous mentioned in sales intelligence.

[88] Zdraveski, Dejan.: *Business intelligence application in performance management*. In: SM. 2009.
[89] Zdraveski, Dejan.: *Business intelligence application in performance management*. In: SM. 2009.

However even if the term is self-explanatory, it is important for a complete view of the BI applications, to explain why visualization tools are so frequently used.

Data visualization is practically a representation of the information and the data that has been collected so far in a graphical form. For many people, pictures are much easier to understand than numbers or the written word, consequently, in this way current changes, patterns, and trends are more easily detected. Data is generally presented in the format of a table, graph, or map. Each kind of visual format is built for a certain kind of presentation so that it can interpret the data in the best possible way.[90] In the paper we describe some of most used formats of data visualization. These representations provide different ways to depict data based on its nature and the insight users aim to derive.

Bar chart is most used for numerical information and for comparison, while Line Graph is more suitable for evaluating the tendency of behaviour over time. Bar graphs plot data in two forms, horizontally and vertically. Their main purpose is to sort or compare the data in the bars. The length of these bars depends on the value they represent. Bar graphs are mainly used to evaluate data. They compare and examine at least two or more values.[91] Figure 3.3 shows the distribution of the app's user base across different device types and the difference between vertical and horizontal data presentation.

[90] Altexsoft.: *A Complete Guide to Data Visualization in Business Intelligence: Problems, Libraries, and Tools to Integrate, Free Data Visualization Tools*. [online]. <https://www.altexsoft.com/blog/data-visualization-tools-types-techniques/>

[91] Streit, Marc.: *Points of View: Bar charts and box plots*. In: Nature Methods. 2014. Vol. 11, No. 2, p. 117

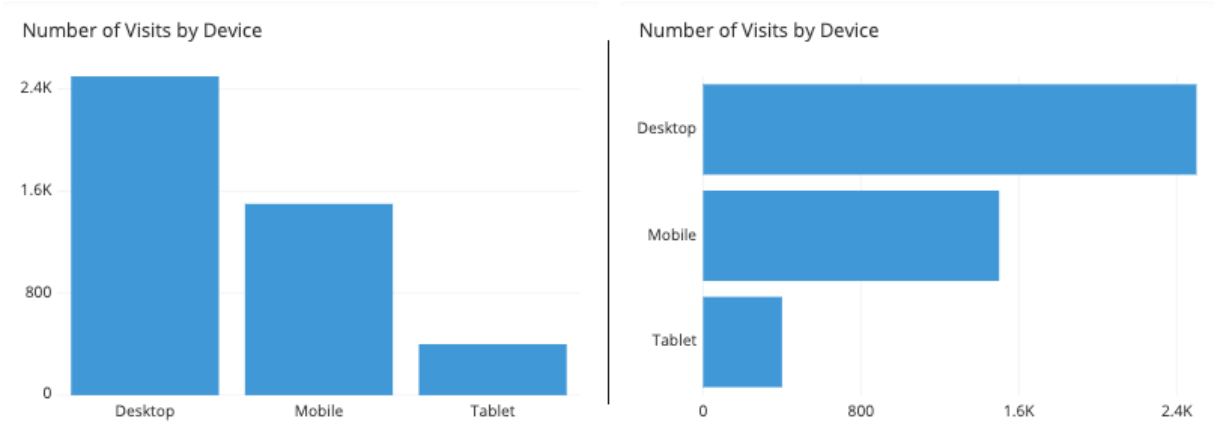

Figure 3.3 Horizontal and vertical bar graphs of the distribution of the app's user base across different device types

Like bar charts, line charts commonly use horizontal and vertical axes for visualization. Line graphs record individual data points, connect them, and thus determine the changes that occurred from one point to another. Line graphs are used to show changes over a certain time frame and allow their user to quickly evaluate accelerations, decelerations, and volatility (depends how the lines are curved).[92] Figure 3.4 shows the time series between expenditures and months. The goal is to visualize the change in spending in individual geographic locations from one point in time to the next.

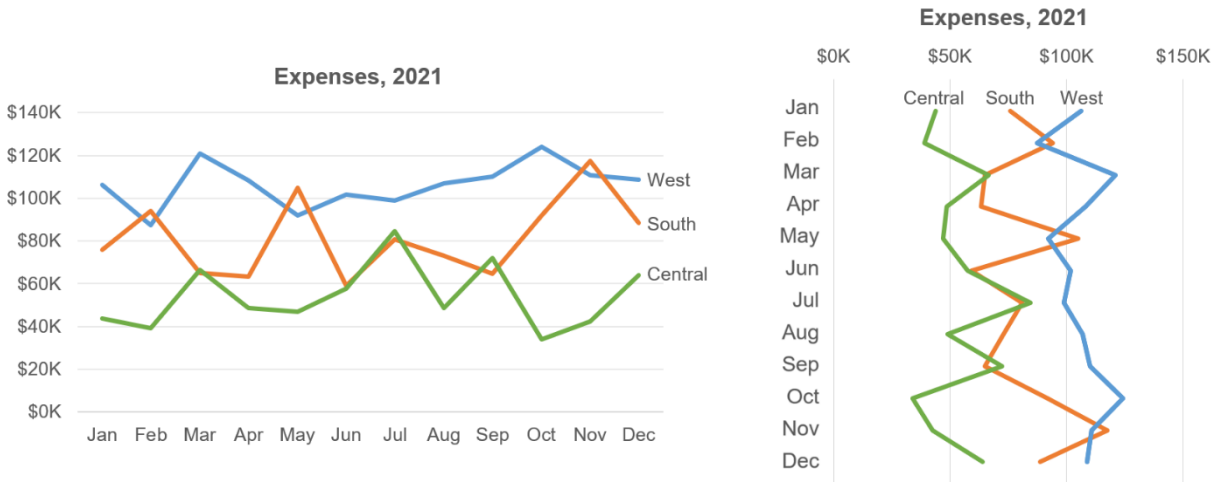

Figure 3.4 Line graphs representing the expenses over the year 2021

[92] Talmadge, Carolyn. Gale, Jonathan.: *Introduction to Data Visualization Techniques: Using Microsoft Excel 2016*. [online]. <https://sites.tufts.edu/datalab/files/2016/08/Introduction_to_Data_Visualization_11.2018.pdf>

When describing the composition of an object, a Pie chart is the most appropriate choice, and when dividing a certain complex object, a Scatter plot, or a Box plot.[93] Pie charts are mostly used to show different categories at a single point in time. The individual categories of the pie chart are divided into parts that represent the proportions of the whole, usually 100%.[94] Figure 3.5 again shows the distribution of the app's user base across different device types. It is the same example as in the bar graphs mentioned above. In this case, however, the visualization emphasizes the proportionality of individual devices and does not show a specific number of visits for each device.

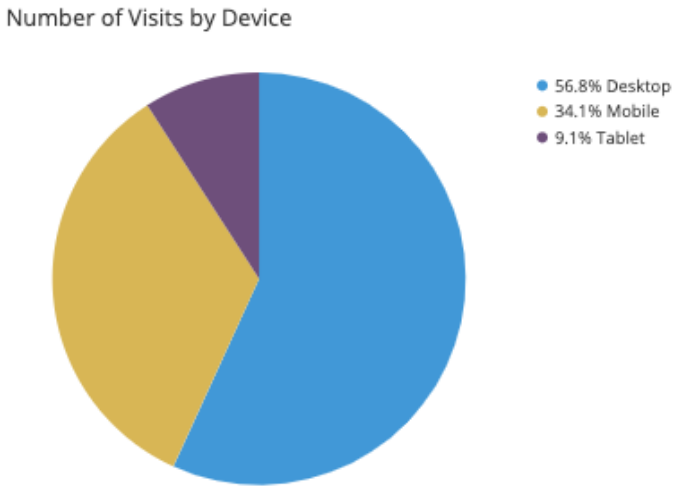

Figure 3.5 Pie chart of the distribution of the app's user base across different device types using pie chart.

Scatter plots, thanks to horizontal and vertical axes, plot objects to visualize the relationship between them. They are very similar to line graphs but do not connect data points.[95] Figure 3.6 shows the relationship between the average happiness score and

[93] Altexsoft.: *A Complete Guide to Data Visualization in Business Intelligence: Problems, Libraries, and Tools to Integrate, Free Data Visualization Tools*. [online]. <https://www.altexsoft.com/blog/data-visualization-tools-types-techniques/>
[94] Talmadge, Carolyn. Gale, Jonathan.: *Introduction to Data Visualization Techniques: Using Microsoft Excel 2016*. [online].
<https://sites.tufts.edu/datalab/files/2016/08/Introduction_to_Data_Visualization_11.2018.pdf>
[95] Talmadge, Carolyn. Gale, Jonathan.: *Introduction to Data Visualization Techniques: Using Microsoft Excel 2016*. [online].
<https://sites.tufts.edu/datalab/files/2016/08/Introduction_to_Data_Visualization_11.2018.pdf>

the average income index. Between these two indexes there is a positive correlation. As the average income per individual increases, the average happiness score increases.

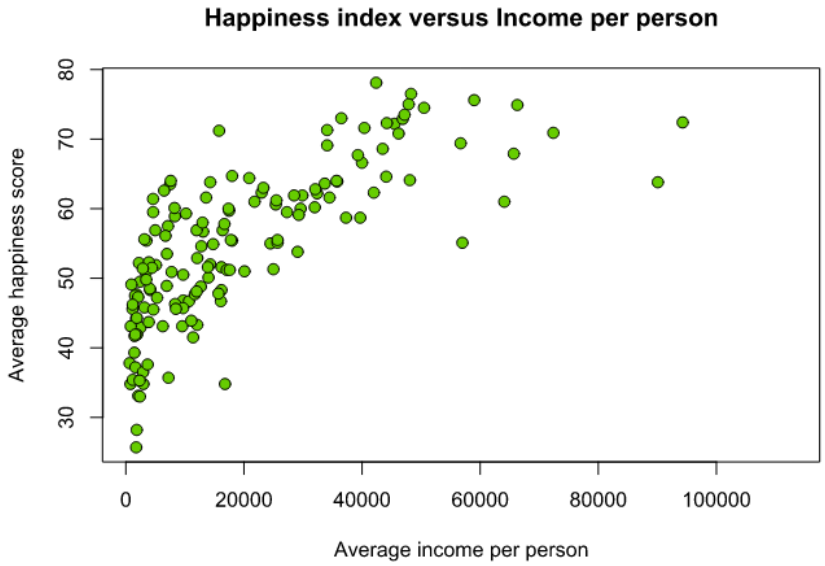

Figure 3.6 Scatter plot representation of the relation between average hapiness score and average income per person.

Box plots are showing five distribution characteristics by position and length, whereby they provide a summary of a large amount data. It shows quarters in horizontal direction.[96] Figure 3.7 shows the distribution of objects and their deviation from the median. The main elements are minimum, maximum and median.

[96] Altexsoft.: *A Complete Guide to Data Visualization in Business Intelligence: Problems, Libraries, and Tools to Integrate, Free Data Visualization Tools*. [online]. <https://www.altexsoft.com/blog/data-visualization-tools-types-techniques/>

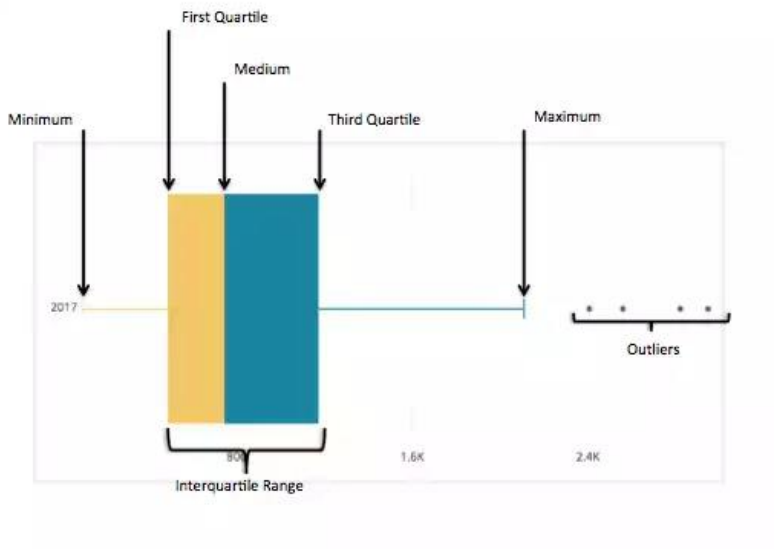

Figure 3.7 Box plot representing the distribution of objects and their divergence from median

For the appropriate presentation of certain data, it is advisable to know which of the already mentioned formats to choose, so that the information and essence is clear and distinct.

Using data presented in this form simplifies also the most complex data by summarizing them into concise and intuitive visual forms, instead of analyzing spreadsheets or large datasets users can now quickly grasp the main patterns, trends, and relationships through visual representations. Even the least experienced employees can gain insights from data thanks to BI systems. The organization no longer needs trained scientists to analyze the acquired data, as the data thus visualized can be presented directly to shareholders, other departments, or teams (in the Fig. 3.8 one example of data visualization).[97]

[97] Bergen, Adair.: *Business Intelligence Applications: Understanding the Application of BI*. [online]. <https://www.selecthub.com/business-intelligence/4-key-bi-applications/>

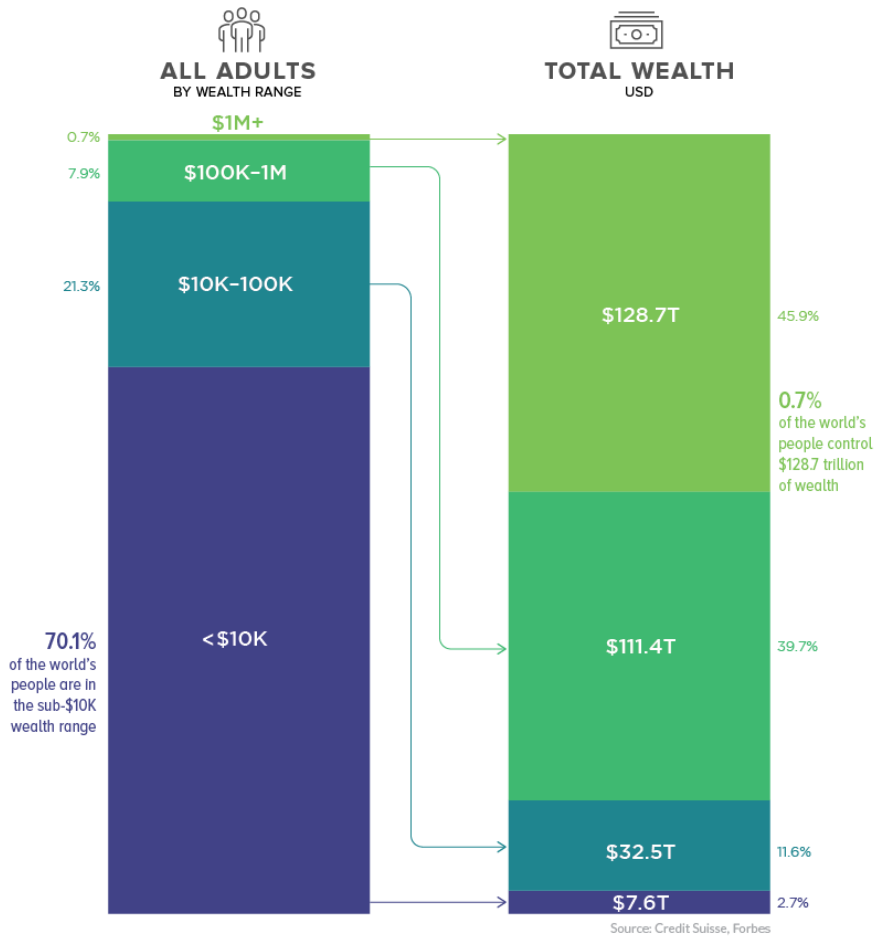

Figure 3.8 Data Visualisation. This figure shows how data visualisation affect the way we perceive information. As you can see, the graphic is showing the global distribution of wealth. It is clear from the figure that only one percent of the population owns more wealth than any other group of the total population.

In the new models of BI Data visualization, it is possible to interact with the data by drilling down, filtering, and exploring various dimensions. This interactivity allows users to explore different scenarios, compare variables, and gain deeper insights. By dynamically manipulating the visualizations, users can quickly identify relationships, patterns, and outliers that may not be immediately apparent in static reports. Another advantage is that visualizations enable teams to discuss and analyze data together, fostering a collaborative environment, and facilitating collaboration among team members by providing a shared understanding of the data. Furthermore, interactive visualizations can be easily shared across different platforms or devices, allowing

stakeholders to access and explore the data at their convenience. By leveraging visual representations, organizations can extract valuable insights from data and make data-driven decisions with greater confidence and efficiency.[98]

3.4) Reporting

A reporting BI application is a software tool or platform specifically designed to facilitate the creation, management, and distribution of reports based on data analysis and insights gathered from a business intelligence (BI) system and it is widely considered a key tool and critical BI application. It can be used in any possible sector of the company, eventually also combined with visualization tools. It provides users with the ability to generate, customize, and share reports that communicate important information and findings derived from the underlying data. There are several types of BI reports. Descriptive reports are used to track long-term performance or identify changes and include an overview of past performance along with current trends. Diagnostic reports describe the reasons for the emergence of a certain situation, thereby also determining potential risk areas. Predictive reports provide insight into future forecasts, which can estimate the future performance of an organization. Prescriptive reports suggest procedures for achieving desired results. [99]

[98] Zebra BI.: *How to Choose Visualization in Power BI*. [online]. <https://zebrabi.com/advanced-guide/how-to-choose-visualization-in-power-bi/>
[99] Kowieski, Jon.*: Business intelligence reporting: From data to decisions*. [online]. <https://www.thoughtspot.com/data-trends/business-intelligence/business-intelligence-reporting>

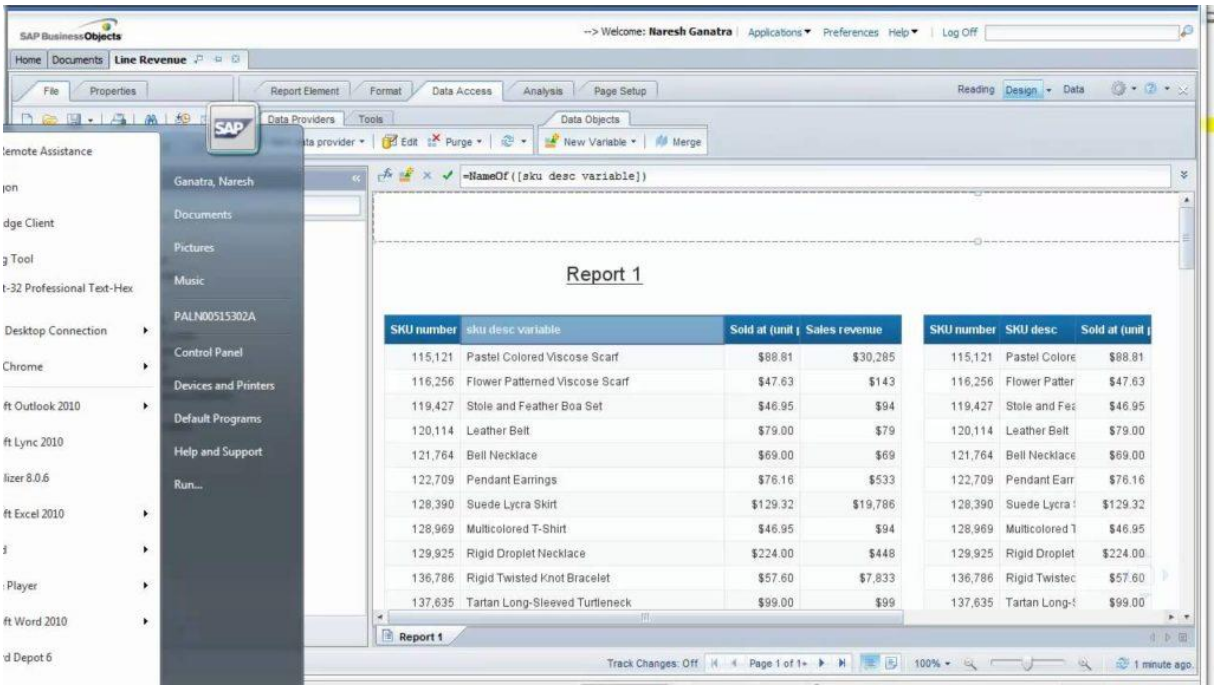

Figure 3.9 Example of reporting program SAP.

BI applications, in addition, offer the flexibility to create customized reports tailored to every specific business needs. Users can select the data sources, metrics, dimensions, and filters to include in the report. This customization allows users to focus on the most relevant data and generate reports that address their specific requirements, whether it's sales performance, financial analysis, customer behavior, or any other aspect of the business. It is also possible to schedule and automate report generation and distribution. Users can define the frequency (daily, weekly, monthly, etc.) and how to share them, possible channels are email, online portals, or embedded applications.[100] Collaboration features allow users to add comments, annotations, or collaborate on shared reports, enabling discussions, data-driven conversations, and fostering a collaborative decision-making environment. These features ensure that the right stakeholders receive timely and consistent reports without the need for manual intervention. Automated reporting

[100] Infor.: *Create flexible, customized financial reports in Microsoft Excel*. [online]. <https://www.tascoli.com/wp-content/uploads/2012/02/F9-Brochure.pdf>

saves time, eliminates errors, and ensures that decision-makers have up-to-date information readily available.[101]

Other functionalities are:

- Ad Hoc Reporting, allows to create on-the-fly reports for immediate analysis and decision-making, enabling users to explore data, define custom queries, and generate reports in real-time, in this way is possible to quickly respond ad hoc analysis requests, without relying on predefined templates or IT support.[102]
- Drill-Down and Drill-Up Capabilities, allow users to navigate through hierarchical data structures. Users can drill down from high-level summary reports to detailed information or drill up to view aggregated data. This interactivity enables users to investigate the underlying factors contributing to specific data points and gain deeper insights into the data.[103]

[101] Tableau.: *Business Intelligence (BI) Reporting: A Guide To The Basics*. [online]. <https://www.tableau.com/learn/articles/business-intelligence/reporting-basics>
[102] Calzon, Bernardita.: *What Is Ad Hoc Reporting? Your Guide To Definition, Meaning, Examples & Benefits*. [online]. <https://www.datapine.com/blog/ad-hoc-reporting-analysis-meaning-benefits-examples/>
[103] O´Connor, Errin.: *How To Use Drill Down & Drill Up In Power BI*. [online]. <https://www.epcgroup.net/how-to-use-drill-down-drill-up-in-power-bi/>

CHAPTER 4 QLIKVIEW: SHORTAGE APPLICATION OF SEWS CABIND

4.1) **SEWS-CABIND and Cable Manufacturing**

4.1.1) Sumitomo Group

The Sumitomo Group is one of the largest industrial groups in Japan and is involved in a wide range of sectors, with three companies of the group (Sumitomo Mitsui Banking Corporation, NEC and Sumitomo Electric Industries) listed by the Financial Times as one of the world's top 500 companies by capitalization. The management of each company of the group is independent, but the origins and core values are common and go back to the founder Masatomo Sumitomo, a Japanese Buddhist monk who lived five centuries ago.[104]

SEWS-CABIND is owned by Sumitomo Electric Group (SEG), through the shareholdings of the two parent companies Sumitomo Wiring System Ltd. and Sumitomo Electric Industries Ltd. The company operates in SEG's automotive business segment, designing and manufacturing wiring harnesses for the transmission of electrical energy to various vehicle components.[105]

SEWS-CABIND was officially founded on 4 May 2001, when the original company Cabind Automotive S.p.A., operating in the field of wiring harnesses for the "white goods" market (i.e. washing machines, refrigerators, dishwashers, etc.), was acquired by the Sumitomo Electric Group. Sumitomo Wiring Systems Ltd. had already been

[104] Sews Cabind.: *Sumitomo History*. [online]. <http://www.sews-cabind.com/company/sumitomo/sumitomo-history/>
[105] Sews Cabind.: *Sumitomo Electric Group*. [online]. <http://www.sews-cabind.com/company/company-profile/sumitomo-electric-group/>

working with Cabind S.p.A. since 1996, with a Technical Assistance Agreement relating to projects for the Fiat Group.[106]

The new company thus emerged from a common ground, developed over years of partnership and sharing of know-how. The target sector is the automotive industry and the designated location is Collegno, small municipality near the city of Turin. In a short time, the Moroccan and Polish subsidiaries of Cabind Automotive S.p.A. also became part of the newly formed SEWS-CABIND.[107]

The aim of the operation was clear from the outset: expansion in the wiring harness sector (which already included some production companies of the Sumitomo Electric Group), to become a supplier to automotive companies in Europe.[108]

A distinguishing feature of SEWS-CABIND is the pliability of its processes and a consequent speed of response to any customer requirement. The strength and financial stability of a large company are mixed with the flexibility and adaptability typical of a small company. This union is the real added value of SEWS-CABIND, it was achieved thanks to a concept strongly experienced by every level of the company: making the customer's needs its own and taking them as a target to be reached.[109]

A syncretism between the typical Italian culture and the rigorous mentality of Japan, between standardization of production and production workflows, better product quality and safer industrial environments. Major customers include Stellantis, IVECO and CNH.

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[106] Swes Cabind.: *SEWS-CABIND – Added Value*. [online]. <http://www.sews-cabind.com/company/company-profile/sews-cabind-added-value/>
[107] Sews Cabind.: *SEWS-CABIND – Added Value*. [online]. <http://www.sews-cabind.com/company/company-profile/sews-cabind-added-value/>
[108] Sews Cabind.: *SEWS-CABIND – Added Value*. [online]. <http://www.sews-cabind.com/company/company-profile/sews-cabind-added-value/>
[109] Sews Cabind.: *SEWS-CABIND – Added Value*. [online]. <http://www.sews-cabind.com/company/company-profile/sews-cabind-added-value/>

4.1.2) The SEWS-CABIND Group organization

Sews-Cabind group is a global partner in the supply of cable harnesses and components for the automotive industry, it consists of eight production plants and more than 10,000 employees, with three subsidiaries managing different local production sites:[110]

- SEWS-CABIND Maroc S.A.S, with six factories in Ain Harrouda (headquarters), Berrechid and Ain Sebaa.

SEWS-CABIND Maroc S.A.S. is specialised in cables and cable manufacturing and has been on the market since 2001, when it was established as a subsidiary of SEWS-CABIND Italy. In 2013, the headquarters were moved from Casablanca to the neighbouring city of Mohammedia. In addition to the plant in Ain Harrouda, there are now three other production sites with a total of 6500 employees: Aïn Harrouda, Berrechid, and Aïn Sebaâ.[111]

Moroccan production is mostly destined for the customer Stellantis, to whom the company undertakes to deliver products in a record time of about three hours. Worthy of note is the special attention given to the female workforce, which is fully included in a development and career support programme, and the commitment to Corporate Social Responsibility initiatives.

- SEWS-CABIND Poland sp.z.oo, with two historical factories in Zywiec;

SEWS-CABIND Poland sp.z.oo specialises in the production of cable harnesses and has been on the market since 2001, when the company was established as a subsidiary of SEWS-CABIND Italy. The headquarters are in the town of Zywiec, a picturesque centre situated in the valley of the same name, 90 km south-west of Krakow. The company's history sees the acquisition of the Leśnianka factory in 2001 and the

[110] Sews Cabind.: *The Group*. [online]. <http://www.sews-cabind.com/company/company-profile/the-group/>
[111] Sews Cabind Maroc.: *SEWS CABIND MAROC*. [online]. <http://www.sews-cabind.com/scm/>

expansion of the Grunwaldzka production site in 2013, in order to meet the ever-increasing demand from customers.[112]

The company now has two cable harness production plants, both in Zywiec and employs around 1400 people, boasting an important regional and European record with the production of more than 900 different types of automotive cable harnesses.[113]

As in every SEWS-CABIND company, there is a strong focus on Corporate Social Responsibility initiatives in Poland, in which employees and their families enthusiastically participate. One of the most heartfelt projects is the World clean up, which has been held annually since 2012. Open days and family days are also recurring.[114]

- SEWS-CABIND Albania Sh.p.k, where the latest factory opened in Bathore Kamez is its headquarters.

SEWS-CABIND Albania Sh.p.k specialises in the production of wiring harnesses for the European automotive industry. Founded as a new company of the Sumitomo Electric Group (SEG) in August 2019, it immediately sees a trend of rapid growth, becoming a solid company with around 1000 employees. It soon consolidates itself as the first and largest wiring harness production company in the Tirana area, increasingly moving towards a lean and flexible production model.[115]

Like all companies in the group, SEWS-CABIND Albania is committed to concretely adopting its principles, not only in terms of production processes, but also in the creation of a strong team inspired by the Sumitomo Spirit from the very beginning.[116]

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[112] Sews Cabind Poland.: *SEWS CABIND POLAND*. [online]. <http://www.sews-cabind.com/scp/>
[113] Sews Cabind Poland.: *SEWS CABIND POLAND*. [online]. <http://www.sews-cabind.com/scp/>
[114] Sews Cabind Poland.: *SEWS CABIND POLAND*. [online]. <http://www.sews-cabind.com/scp/>
[115] Sews Cabind.: *The Group*. [online]. <http://www.sews-cabind.com/company/company-profile/the-group/>
[116] Sews Cabind.: *The Group*. [online]. <http://www.sews-cabind.com/company/company-profile/the-group/>

4.1.3) Wiring production process

The wiring harness can be regarded as the central nervous system of the vehicle, as it is responsible for the connection between hardware and electronic parts.

The design phase of the wiring harness involves numerous variables. The first among them is the structure of the vehicle. The variety of the wiring harness depends first and foremost on the configuration and functions of the vehicle on which it is to be installed, and not least on the electronic components to be connected by the wiring harness and the customer-specific components. It follows that these are one of the last parts of the vehicle to be designed but among the first to be built in the body-in-white phase of the assembly line.

Often the most advanced design processes make use of digital prototyping or Digital Mock-Up (DMU) tools that allow the simulation of assemblies and interactions between the different components, serving as a basis for product development and enabling verification already in the very early stages of vehicle development.

The completion of the design phase leads to the generation of the bill of materials (BOM). The Bill of Materials (BOM) is a document that defines all the elements required to manufacture a given product. In the machine tool industry, it takes two different forms: the Engineering BOM (EBOM), a BOM created by engineers during the design phase, and the Manufacturing BOM (MBOM), which is also used to plan the purchase of raw materials. The BOM therefore highlights the components and cables required for the realization of the cabling. It is based on customer demand and the production and delivery times of the required cabling that the logistics department plans material deliveries. The production phase of a harness thus begins with the arrival of the materials listed in its BOM.

The second phase is called Incoming Quality Inspection or Incoming Quality Check (IQC). During this phase, the Plant Incoming Inspection department has the task of

verifying that the materials received from suppliers meet the required standards by conducting laboratory investigations. Once the checks have been passed, the cables and components are moved to the warehouses to await use in production.

The first activity performed during the production phase of the cabling is the cutting of the cables with special cutting-machines, so that the length corresponds to what was defined in the design phase. This is followed by the crimping procedure, during which the wire with stripped insulation is crimped into the wire barrel section of the terminal, so that the electrical connection and retention force of the cable is guaranteed. At the end of the process, which is useful for enabling the cables to be used in both data exchange and electrical transmission, strict quality tests are carried out using special devices or platforms.

The next step involves stripping the ends of the wire opposite to where the crimping was performed and the cores remain uncovered, so that they can later be used for connecting terminals, connector housings or modules.

This is followed by the process of twisting, or twisting of the wires, to eliminate the electromagnetic interference that the electrical current flows for which the wiring is used may cause.

Once the twisting is performed, we move on to the phase of welding the cables using ultrasonic welding machines, whose welding technique consists of applying light pressure by means of mechanical oscillation at high frequencies. This joining technique is particularly suitable for non-ferrous metals such as copper, aluminums, and their alloys. Note that the bonding phase takes place in the solid state, i.e., without any melting of the parts to be joined, by means of low-pressure, high-frequency oscillations, creating a permanent, solid and metallurgically pure connection in a fraction of a second.

The moulding process, which follows ultrasonic soldering, consists of placing the cables in special moulds where a molten thermoplastic material is injected, which, once cooled, will solidify mechanically attaching the connectors to the cables.

In this way, cables and connectors become one piece, with high resistance to vibrations and shocks and an excellent level of flexibility.

The production of the cable harnesses concludes with taping, the purpose of which is to bundle the cables and protect them from the weather and possible shocks.

The harnesses are then assembled, a stage in which it is also verified that they meet the requirements identified in the design specifications.

4.2) Supply criticism and COVID crisis

4.2.1) General Supply criticism

As we have seen, the organizational structure of Sews Cabind is very complex, considering the headquarter plus the various subsidiaries the company owns and administers logistics hubs and plants in four countries and on two continents. Even without taking into account the flows with other companies of the Sumitomo group located around the world or other small third-party suppliers (legally independent, but nevertheless included in the planning system of the Italian headquarter), the supply chain management may present non-trivial challenges. The various departments of logistics, planning and warehousing are well organized and coordinated in handling the various daily operations. But to these standard situations must be added other common problems, encountered when it comes to supply chain management. One of these, is the relationship with suppliers.

Delays or non-deliveries are very important variables to take into consideration for B2B company as Sews Cabind, especially in a competitive environment such the automotive industry. Suppliers might try:

- to delay a shipment in order to supply first more important customers,
- receive last minute orders (paid at a premium) and decide to divert their goods,
- or even more trivially suffer transport delays or production problems.

Of course, the delay on the delivery of raw materials or components by Sews Cabind's suppliers, spills over into the subsequent delivery of finished products to the Sews Cabind's customers. To give an idea of the consequences that this implies, let's take as an example the Ducato case.

The Fiat Ducato is a light commercial vehicle produced since 1981 by Fiat. The production is managed by a joint company called Sevel ("Società Europea Veicoli Leggeri"), owned by Fiat and PSA, each with a 50% share. The various generations have also been produced under other brands of the Fiat-Chrysler group and PSA. The Fiat Ducato is characterized by very high production volume, the production rate is estimated in 90,000 vehicles per year (7,500 per month). It is clear that working at these rates, a stop of the production line would result in non-negligible losses for the customer company. Sews Cabind has the entire supply (100%) of the wiring system of the Ducato model. In the event of delivery delays and consequent stop of the production line, Fiat in order to hedge against this risk, settled up, by contract, penalties that would consist in 9 million € penalty per day of stop line. Obviously for a company with revenue of €22 million per year (considering only Sews Cabind Italy), this is not a scenario that can be taken into consideration.

4.2.2) Shortage: Automotive industry

These already existing supply chain problems were highlighted during the notorious semiconductor and chip crisis that occurred during the COVID period and became unsustainable, causing disruptions throughout the supply chain.

The global shortage of semiconductors, which began at the beginning of 2021, stopped assembly lines around the world, as long lead times for silicon chips have slowed down the production of all kinds of products, from smartphones to home appliances to driver assistance systems. The main car manufacturers suffered significant reduction in production, with consequent revenues losses by several billion dollars. In the first few months of the COVID-19 pandemic, car sales fell by 80% in Europe, 70% in China and almost 50% in the United States. The lack of demand for new cars led to car factories closing and millions of workers put in stand-by. Consequently, orders for semiconductors, used in plenty of areas, including fuel pressure sensors, digital speedometers, and navigation screens, collapsed. Semiconductor shortage was not caused by a single incident or malfunction, but multiple confluence of events contributed to it.[117]

4.2.3) Shape of the semiconductors demand

In the second half of 2020 sales of new vehicles grew but carmakers did not significantly increase semiconductor orders because of the various ups and downs in the sales forecast and also because of the market uncertainty at the time. At the same time, the COVID-19 pandemic led to a surge in demand for consumer electronics, such as laptops, tablets, and gaming consoles, as people shifted to remote work and online

[117] Burkacky, Ondrej.: *Coping with the auto-semiconductor shortage: Strategies for success*. [online]. <https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/coping-with-the-auto-semiconductor-shortage-strategies-for-success>

entertainment. [118] This increased demand for semiconductors, which are essential components in these devices. This means that although the automotive industry has significantly reduced its chip orders, other industries have faced increased demand. The need of semiconductors did not lower but it just reshaped.[119]

In recent years, the semiconductor industry has matured through consolidation and the achievement of greater scale. Its capacity has grown modestly but costantly, in line with sales. Generally, semiconductor industry's capacity utilisation has been consistently high (80% or more) over the last decade. Indeed, (according to IHS-Omdia) utilisation in 2020 was close to 90%, which many industry leaders consider full utilisation, as exceeding this level often results in disproportionately longer lead times. Thus, although the semiconductor industry has increased its production capacity by almost 180% since 2000, its total capacity is almost exhausted at the current high utilisation rate.[120]

4.2.4) Inventory Strategies

Typical automotive component purchasing contracts are significantly different from those in other industries. Just-in-time manufacturing practices are widely used in the automotive supply chain, which can minimize waste and increase efficiency by keeping inventories low. That's why the supply cycle of chips for the automotive industry tends to be shorter, especially for binding purchase commitments of a few weeks or months. Normally, reducing inventory is financially beneficial; however, in the event of unexpected shortages, this practice causes immediate disruption to the entire supply

[118] Burkacky, Ondrej.: *Coping with the auto-semiconductor shortage: Strategies for success*. [online]. <https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/coping-with-the-auto-semiconductor-shortage-strategies-for-success>
[119] King, Ian. Wu, Debby. Pogkas, Dementrios.: *How a Chip Shortage Snarled Everything From Phones to Cars*. [online]. < https://www.bloomberg.com/graphics/2021-semiconductors-chips-shortage/>
[120] Burkacky, Ondrej.: *Coping with the auto-semiconductor shortage: Strategies for success*. [online]. <https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/coping-with-the-auto-semiconductor-shortage-strategies-for-success>

chain. Given that many operators did not expect chip shortages in 2020 and 2021, it is likely that they had very limited stocks to cope with the crisis.[121] The situation differs for other industries, which are more likely to be governed by binding long-term contracts and provide semiconductor suppliers with purchase orders that exceed six to twelve months. Additionally, as a result of geopolitical tensions, some consumer electronics manufacturers have significantly increased their chip inventories to overcome a period of limited access to semiconductor production.[122]

4.2.5) Bullwhip Effect

Sews Cabind, as we saw, is a wiring system producer. The company has suffered from rising raw material prices, including copper, a key material in the cable industry. But it was not directly involved in the semiconductors and chips crisis, because those latters are not main components of the compay's products, although they are still partially used, given the company's product differentiation. Unfortunately, the semiconductor shortage has had a bullwhip effect throughout the automotive supply chain and also beyond with other industrial players struggling to obtain chips. The bullwhip effect refers to the phenomenon of amplifying demand fluctuations as they move upstream in a supply chain. These demand fluctuations become more pronounced as they propagate upstream from the customer to the manufacturer and further up the supply chain. In fact, Tier 1 and Tier 2 suppliers, who provide various components and systems, have been affected by the reduced demand from automakers. This, in turn, affected smaller

[121] Korsh, Shayna.: *COVID-19, Supply Chain Shortages, and the Automobile Industry. In: Michigan Journal of Economics*. [online]. < https://sites.lsa.umich.edu/mje/2022/01/05/covid-19-supply-chain-shortages-and-the-automobile-industry/>

[122] Burkacky, Ondrej.: *Coping with the auto-semiconductor shortage: Strategies for success*. [online]. <https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/coping-with-the-auto-semiconductor-shortage-strategies-for-success>

suppliers and created a domino effect of disruptions across the entire supply chain, involving even Sews Cabind.[123]

4.3) **QlikView: Shortage application**

4.3.1) Qlik

Qlik is a software company specialized in data analytics and business intelligence (BI) solutions. Founded in 1993, the company has established itself as a leading player in its industry, providing innovative products and services that help organizations transform their data into actionable insights.[124]

Over the years, a wide network of partners was established, including technology vendors, system integrators, and consultants, to deliver comprehensive solutions and services to customers. The company also made multiple strategic acquisitions to enhance its product portfolio and expand its capabilities, especially in innovative sector like AI, or in complementary sectors in order to vertical integrate.[125] Notable acquisitions include Attunity (data integration), Podium Data (data cataloging), and Blendr.io (integration platform as a service). Thanks to these choices, Qlik has secured a strong global presence and serves thousands of customers, including both large enterprises and small to medium-sized businesses, across various industries such as finance, healthcare, manufacturing, retail, and more.[126]

[123] Wayland, Michael.: *How Covid led to a $60 billion global chip shortage for the auto industry*. [online]. <https://www.cnbc.com/2021/02/11/how-covid-led-to-a-60-billion-global-chip-shortage-for-automakers.html>
[124] Qlik.: *Us*. [online]. <https://www.qlik.com/us/company>
[125] Packt.: *A history of Disruption*. [online]. <https://subscription.packtpub.com/book/big-data-and-business-intelligence/9781782173359/1/ch01lvl1sec08/a-history-of-disruption>
[126] Avidon, Eric.: *Qlik launches new cloud-based data integration platform*. [online]. <https://www.techtarget.com/searchbusinessanalytics/news/252526899/Qlik-launches-new-cloud-based-data-integration-platform>

Qlik offers a range of products and solutions that cater to different data analytics needs. Some of its key offerings include:

- QlikView is the most representative product, guided analytics and dashboarding solution. It provides a comprehensive BI platform for creating interactive and visually appealing dashboards, reports, and applications.[127]

- Qlik Sense is one of the last products launched, a self-service data analytics platform that enables users to create interactive visualizations, explore data, and share insights. Qlik Sense is designed for ease of use, allowing both technical and non-technical users to analyze data and make data-driven decisions.[128]

- Qlik Nprinting is a reporting and distribution solution that works seamlessly with Qlik Sense and QlikView. It allows users to create professional reports and distribute them in various formats, such as PDF, Excel, PowerPoint, and HTML.[129]

- Qlik Data Integration (formerly known as Attunity) offers a suite of data integration and data management tools. It enables organizations to efficiently extract, transform, and load (ETL) data from multiple sources, ensuring data quality and accessibility for analytics.[130]

The company is committed in promoting data literacy and empowering users to become more data-driven, there are different training programs and certifications to help individuals and organizations develop data literacy skills and leverage data effectively. Through the years an active user community and partner ecosystem has emerged with

[127] Visual Intelligence.: *Qlik View: beginning of modern analytics*. [online]. <https://www.visualintelligence.co.nz/qlikview/>
[128] Qlik.: *Qlik Sense*. [online]. <https://www.qlik.com/us/products/qlik-sense>
[129] Qlik.*: Power up your analytics with enterprise reporting: Qlik Nprinting*. [online]. <https://www.qlik.com/us/-/media/files/resource-library/global-us/direct/datasheets/ds-qlik-nprinting-en.pdf?rev=2f14981ba00f49dc80d504a501d9fec5>
[130] Qlik.: *Qlik Data Integration*. [online]. <https://www.qlik.com/us/products/qlik-data-integration>

the aim to provide a platform for users to collaborate, share best practices, and get support from experts.[131]

4.3.2) QlikView

QlikView is the first product launched by the company just after its founding date. There have been several changes and upgrades since the first version of the product, we recall the various versions QlikView, QlikView2, ..., QlikView7 up to the current version. All this makes this product the flagship of the company. To this date there are more recent products such as QlikSense, on which the company focuses more, these are easier and more intuitive to use but on the other hand they lose in the ability to do more in-depth and structured analysis.[132]

QlikView is a data discovery and visualization tool, it enables users to discover insights and visualize data in a highly interactive and user-friendly manner. It allows users to navigate and explore data freely, without the need for predefined queries or complex programming. Users can create visually appealing dashboards, reports, and interactive data visualizations to gain insights and make data-driven decisions.[133]

One of the key differentiators to the others BI platforms, is its associative data indexing technology.

Traditional BI tools typically use a query-based approach, where data relationships need to be predefined and explicitly joined before analysis. On QlikView, and in general all Qlik's BI products, on the other hand, data associations are established on the fly, every data point is associated automatically with all other related data points, creating a network of associations across multiple data sources and tables that enables

[131] Qlik.: *Data Literacy*. [online]. <https://www.qlik.com/us/bi/data-literacy>
[132] Qlik.*: Qlik View*. [online]. <https://www.qlik.com/us/products/qlikview>
[133] Data flair.: *Top 10 QlikView Capabilities – Why QlikView is Best BI Tool?*. [online]. <https://data-flair.training/blogs/qlikview-capabilities/>

dynamic exploration and analysis. In addition, with associative data indexing, when a user selects a data point, all associated data points are dynamically recalculated, allowing for instant exploration and analysis of data subsets. In this way calculations are performed on the fly as users interact with the data, this on-demand calculation ensures real-time responsiveness and agility in data exploration.[134]

Others characteristic of QlikView are:

- Self-Service Analytics: users can create their own data visualizations and explore data independently, without heavy reliance on IT or data specialists.

- Powerful Data Analysis: users can perform calculations, apply filters, create advanced calculations using scripting, and perform complex aggregations (this is one of the main differences between QlikView and QlikSense).

- Collaboration and Sharing: dashboards, reports, and visualizations can be shared with others within the organization, allowing for collaborative analysis and discussions around the data.

- Scalability and Performance: QlikView is designed to handle large volumes of data and provide high-performance analytics. It employs an in-memory data processing approach, where data is loaded into memory for fast and interactive analysis. In this way is possible to optimizes data compression and by the use of associative indexing deliver quick response times, even with complex data models and extensive calculations.[135]

[134] Dgroove.: *Power BI vs Qlik: i due sistemi di business intelligence a confronto*. [online]. <https://www.dgroove.it/power-bi-vs-qlik-i-due-sistemi-di-business-intelligence-a-confronto/5715/#Power-BI-vs-Qlik:-mettiamo-a-confronto-i-due-sistemi>
[135] Data flair.: *Top 10 QlikView Capabilities – Why QlikView is Best BI Tool?*. [online]. <https://data-flair.training/blogs/qlikview-capabilities/>

- Security and Governance: there are robust security features to protect sensitive data and ensure appropriate access controls. Administrators can define user roles, access permissions, and data-level security. The platform also supports auditing, versioning, and data governance capabilities, ensuring compliance with data governance policies and regulations.[136]

- ETL and Data Integration: QlikView offers Extract, Transform, Load (ETL) capabilities that allow users to extract data from various sources, transform it, and load it into the QlikView environment. It supports connectivity to a wide range of data sources, including databases, spreadsheets, data warehouses, and web services. Data integration capabilities help users bring together data from disparate sources for comprehensive analysis.[137]

QlikView has gained recognition in the industry for its user-friendly approach to data discovery and its associative data indexing technology. It has been widely adopted by organizations across various industries to gain insights, drive data-driven decisions, and foster a culture of self-service.

4.3.3) QlikView architecture in Sews Cabind

When you buy a QlikView licence, you obtain legal permission to use the QlikView software, unlocking all the functionality of the application and the right to create, analyse and share interactive dashboards and data-driven reports, in accordance with the terms and conditions of the licence agreement. The terms and conditions can be different since the company also offers other complementary products. Sews Cabind have its own software development team, so it created the various application and all

[136] Qlik.: *Security*. [online]. <https://help.qlik.com/en-US/qlikview/May2023/Subsystems/Client/Content/QV_QlikView/Security.htm>
[137] Data flair.: *Top 10 QlikView Capabilities – Why QlikView is Best BI Tool?*. [online]. <https://data-flair.training/blogs/qlikview-capabilities/>

the architecture, behind the BI, by its own. In alternative is also possible to outsource this job to consultancy agencies or use Qlik's cloud service or data repositories (warehouse), or others possible solutions according to the company's needs. To date, the company has around thirty different applications of BI on QlikView, each of them cover different areas of the company. In this paper we will describe the BI application "Shortage". The architecture behind this application follows the structure shown in chapter two, the data warehouse of the company is composed by different layers, starting from the data sources, internal and external, then ODS, Data Marts, Aggregates and last the Presentation layer. Here we will present them more in detail:

1) The first step is selecting data sources, the main sources of data of the company are ERP system, different software applications, Sequel Server, external files and even Excel documents.

2) The second step the extraction of these data from their original source to the ODS (Operational Data Sources), this operation is very simple, the data are copied with the same parameters that they had in the original databases through QlikView's extraction script, no editing operations are performed.

The ODS is the first layer of the warehouse, where data useful for BI purposes are collected in ".qvd" files. In the QlikView development environment, .qvw and .qvd are file extensions associated with the QlikView software:

- QVW (QlikView Document): A .qvw file is a QlikView Document file. It is the primary file format used to store applications and their associated data and visualizations. A QVW file contains the data model, layout, scripts, and visualizations of a QlikView application, it is essentially a self-contained file that encapsulates all the information required to create and interact with the applications.

- QVD (QlikView Data): A .qvd file is a QlikView Data file. It is a file format used for storing data extracted from various sources. They are structured and compressed for efficient storage inside the platform. These files are created through data extraction scripts and serve as a local data store for the application. QVD files can contain structured tables or raw data.

The .qvw and .qvd files are closely related and work together in the QlikView applications. QVD files serve as a local data cache, improving performance and reducing the need to repeatedly extract data from the original sources. The QVW file is a volatile memory (on-the-fly), it is used to move data from different sources (usually QVD), then utilizes the data from the QVD files to create visualizations, perform data analysis, and generate reports.

3) The third step consist in moving these data (QVD -> QVW -> QVD) in the second layer of the warehouse, Data Mart, we introduced Data Mart in the second chapter. This time some transformations are performed on the data. Inside the Data Mart, there are different files QVD, each of them is composed by data coming from different qvd of the ODS. In this way is possible to perform a first clustering. In the ODS the data is copied with a correspondence 1to1, it means that for every file source there will be a correspondent file qvd in the ODS, with equal aspect. We can imagine the qvd of the data mart as business object, containing all the data related to that specific business (i.e., the Finance qfd in the data mart will take all the financial data even if they are in different qvd in the ODS).

4) The fourth step is the aggregates, here we are near to what will be the output that users will see. One aggregate is a file qfd where calculation is performed using the data coming from the one or more qfd of the data marts, this calculation can be also complex according to the type of analysis that is needed. In the modern BI model user can interact with this layer and create their personalized

aggregation, according to the specific analytic they want to perform, using the data from the data mart, no programing competences are needed. QlikView does not offer this feature, or at least is hard to create your personalized aggregate with no programming skills, but on the other hand is it possible to perform really articulated calculations inside the aggregates.

5) The last step is the presentation layer, where the data can be presented in different ways. It is possible to present more dashboard for one single application such as in Shortage application.

QlikView provide the development environment and gives to the company a certain amount of token. They can be normal or nominal, every normal token gives to one user the access to one single BI application, instead a nominal token gives to one user access to every BI application. The administrator has the responsibility to manage these tokens. The amount of token is agreed by the two parties when the license is bought.

4.3.4) QlikView: shortage

Shortage is one of the thirty QlikView BI applications of the company. It consists of five dashboard, each representing different flows/processes of the company. The shortage application of the platform QlikView is aimed to help the management to face the shortage problem towards two flows:

- the company trying to acquire raw materials/components (suppliers-company flow), here becomes useful to the procurement and suppliers planning department.
- the company selling its finished products (company-consumers flow), here becomes useful to the logistic department.

16 Mar	17 Mar	18 Mar	19 Mar	20 Mar	21 Mar	22 Mar	23 Mar	24 Mar	25 Mar	26 Mar
-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
-5	-11	-11	-11	-11	-11	-11	-11	-11	-11	-11
-5	-11	-11	-11	-11	-11	-11	-11	-11	-11	-11
961	961	961	961	878	752	593	446	203	203	203
-25	-25	-25	-25	-25	-25	-25	-25	-25	-25	-25
-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
0	-1	-1	-1	-2	-2	-2	-2	-2	-2	-2
10	-4	-4	-4	-4	-4	-4	-9	-9	-9	-9
28	28	28	28	28	28	19	12	0	0	0
214	205	205	205	180	165	148	114	69	69	69

Figura 4. 1 Output section of Shortage BI application

The picture above represents the output part:

- red cells mean that the product of the corresponding line is in shortage, the number tells you how much, the corresponding column indicates the date when it will happen.
- green cells mean that there are still stocks of the product in the HUBs, the number tells you how much.

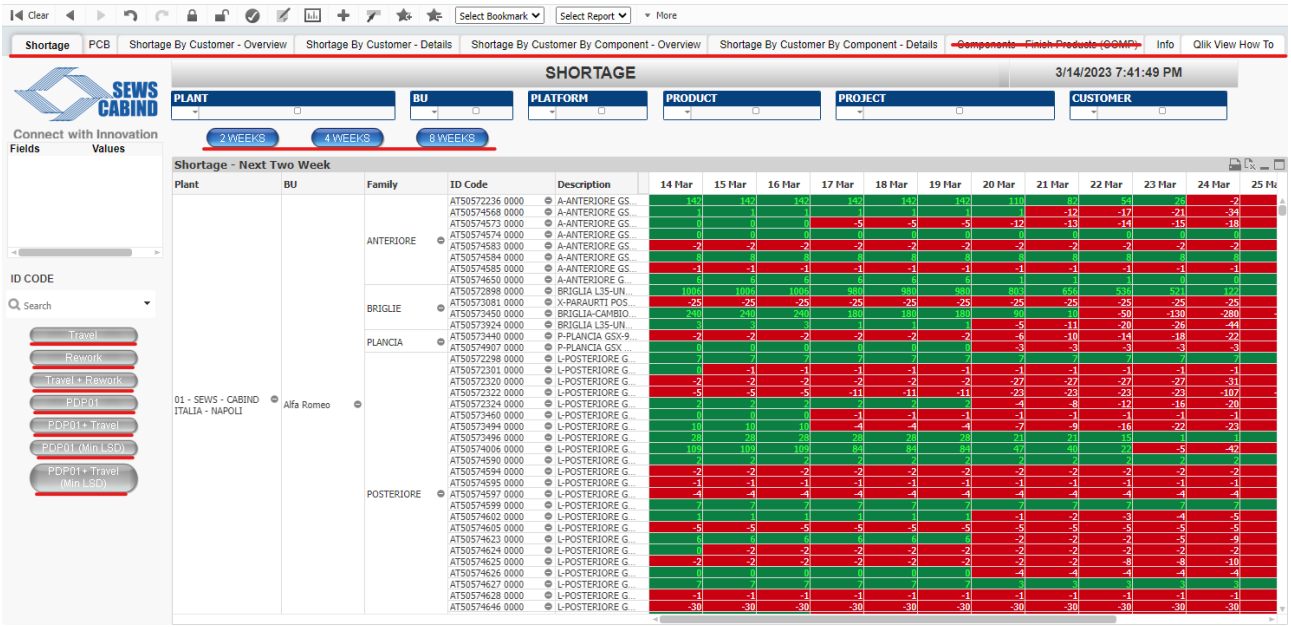

Figura 4. 2 Overview of the Shortage dashboard

As shown in the picture above there are different sections in the panel. First let's analyse the different filters.

Figura 4. 3 Time filters

With these you can select the time horizon of the desired output results.

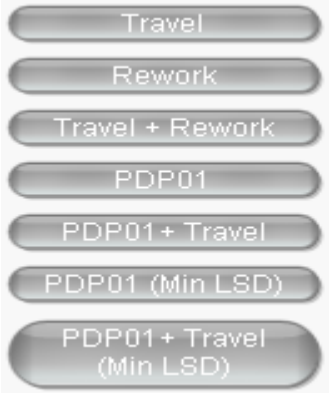

Figura 4. 4 General filters

- Travel: activating this filter also the products, that in this very moment are in travel, will be included in the calculations.
- Rework: activating this filter also the defectives products that are in rework process (to be effective products again) will be included in the calculations.
- Travel + Rework: combination of the previous.
- PDP01: activating this filter also the production plan of the company (Piano di Produzione principale) will be included in the calculations. So, the quantities produced according to the production plan will be added during the calculation of the shortage quantity.
- PDP01 + Travel: combination of the previous.
- PDP01(min LSD(LineStopDate)): activating this filter the production plan of the company, affected by the shortage of the critical component of the product (the one that has the nearest line stop date) will be included in the calculations.

I.e., Suppose we have a product X consisting of three components: A, B and C. To produce X, we need 5pcs of A, 10pcs of B, 20pcs of C (according to BOM). Let us assume that we have 40pcs of each component in stock and a time horizon of 7 days. The MRP foresees an output of 1pc of X per day, and consequently, requirement of

35pcs of A, 70pcs of B, and 140pcs of C weekly. Should production stop we will have in stock enough pieces of A to cover 8 days, enough pieces of B to cover 4 days and enough pieces of C to cover 2 days. So, the Min LSD (worst case) is the C line that will stop first.

When you apply the filter PDP01(min LSD) you put yourself right in this case: the worst case component (component c, in this example)will not be any more produced and consequently the finished product will not be produced after one of the components goes out of stock, then x will be not produced after 2 days, and not in 8/4 (if you stop a/b), and no quantities will be added to the calculation of the shortage after this date.

- PDP01 + Travel (min LSD): combination of the previous.

Shortage

This first dashboard was created before COVID and the related crisis, at that time it was used just by the top executives mainly to detect possible anomalies and to give a base for long term strategies. It represents the most general view of shortage, for every ID code, of finished product, you have a brief description of the product, the family products from which it comes, the BU and the plant where it is present. The output considers just the quantities stock present in the logistic HUBs (plants) and subtract the quantities of the sale plan, for more deep analysis it is possible to activate the different filters (Figure 4.2 shows the the shortage dashboard).

When we talk about finished product, plants listed are not production plants but only logistic warehouses (HUBs of distribution) that are located near the customer, to reduce the lead time and facilitate logistic plans.

Suppliers-company flow

This section is used by procurement and suppliers planning department, the task is to assure constant supply and planning routes of components and raw materials to the production plants.

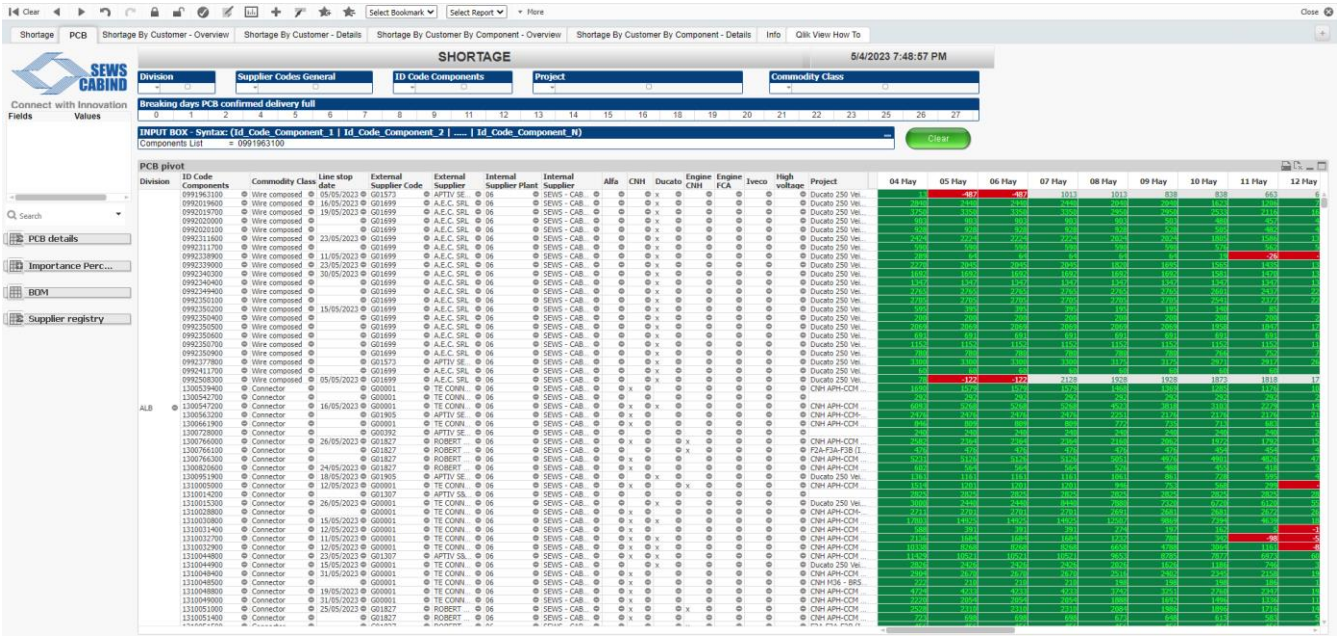

Figura 4. 5 Overview of the PCB dashboard

The elements of the tab are:

- Division, the various division are ALB, MOR, POL, ITA, COMIND and IMELTEL (the last two are independent third small companies, are present in the Sews Cabind system in order to have complete monitoring of the situation). Usually, every product is produced in one single division, it is rare that one product is produced in two different divisions.
- ID Code Components are the Pair Numbers used to identify the different components.
- Commodity Class is a name of internal purpose used to identify groups of components.
- Line Stop Date represents the date when there will be shortage.

- External Supplier Code, is a code by which an external supplier is identified by Sews Cabind
- External Supplier is the name of the supplier.
- Internal Supplier Plant is the code of the internal Plant that supplied the component. Often the components are supplied to the nearest Sews Cabind warehouse or plant, and just after they are sent to the plant or warehouse where the component is needed. Through this data it is possible to understand if the component is coming directly from the supplier or if it passes through a Sews Cabind site first.
- Internal Supplier is the name of the internal warehouse or plant above described.
- Alfa, CNH, Ducato, Engine CNH, Engine FCA, Iveco and High Voltage, are the business unit to which the component belongs, it means that this component will be used to produce a finished product that will be sold to these customers (customers are managed by specific BU). The organisation of the company includes, in addition to the logistics, planning, finance and so on departments, other groups, called business units, which cover all these aspects specifically for a project of the customer. BUs interface directly with the customer, of course they are constantly supported by the other departments.
- Project, this field specifies the project of the BUs above mentioned to which the component belongs.

In these dashboards is not possible to use the filters listed for the shortage dashboard, since here we are dealing with components and raw materials. Hence, production plan, travel and the other filters are not variable but instead they are constraints. These are the filters that can be used:

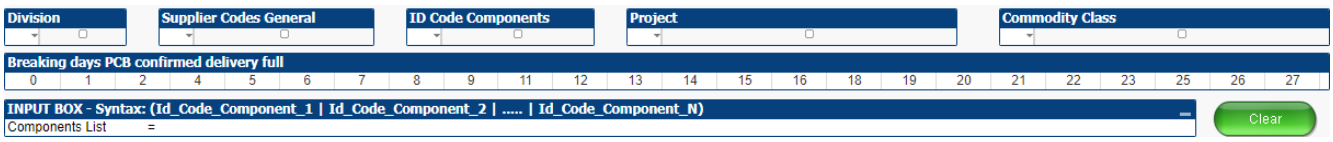

Figura 4. 6 Filters of the PCB dashboard

- Division, if applied only the rows regarding the selected division will be shown,

- Supplier Codes General, if applied only the rows regarding the selected supplier will be shown,
- ID Code Components, if applied only the rows regarding the selected component code will be shown,
- Project, if applied only the rows regarding the selected project will be shown,
- Breaking days PCB confirmed delivery full, procurement and suppliers planning department is in constant contact with the suppliers, generally to suppliers is given the option to confirm that their order will be 100% in time (of course this is not always possible and in general it is not possible to confirm with large time advance). So, applying this filter only confirmed deliveries at 100% are taken into account, in the selected time horizon, the rest is given as in delay and not considered.
- INPUT BOX, it is showing which are the filters activated.

Through the application, the procurement and suppliers planning group monitors which situations might be critical. According to the company's policy one scenario is critical, when a shortage could occur for a component within two weeks. The workers in this group, considering a two-week time frame (easily implemented via filters), proceed to compile a list of all components or raw materials that go into shortage during this interval (red boxes in the output section). After this, individual cases are taken and analysed one by one, trying to understand through the various filters, why this situation occurred (stock in travel, not confirmation of the supply and so on), which are the finished products affected by the shortage of this component and obviously proceed with finding a possible solution to the problem. This last step is done in accordance with the BU related to the critical product, possible solutions include checking whether the critical component can be replaced by another component of other Sews Cabind divisions, soliciting the supplier to supply the component, contacting other suppliers even at an additional price and retaliating against the original supplier through penalties set at the time of the contract.

Company-customers flow

The following section are all managed by the logistic department 3 and 4 look to shortage from a product-component point of view, 5 and 6 from a component-product point of view.

1) Shortage by customer – Overview: from this section it is possible to see:

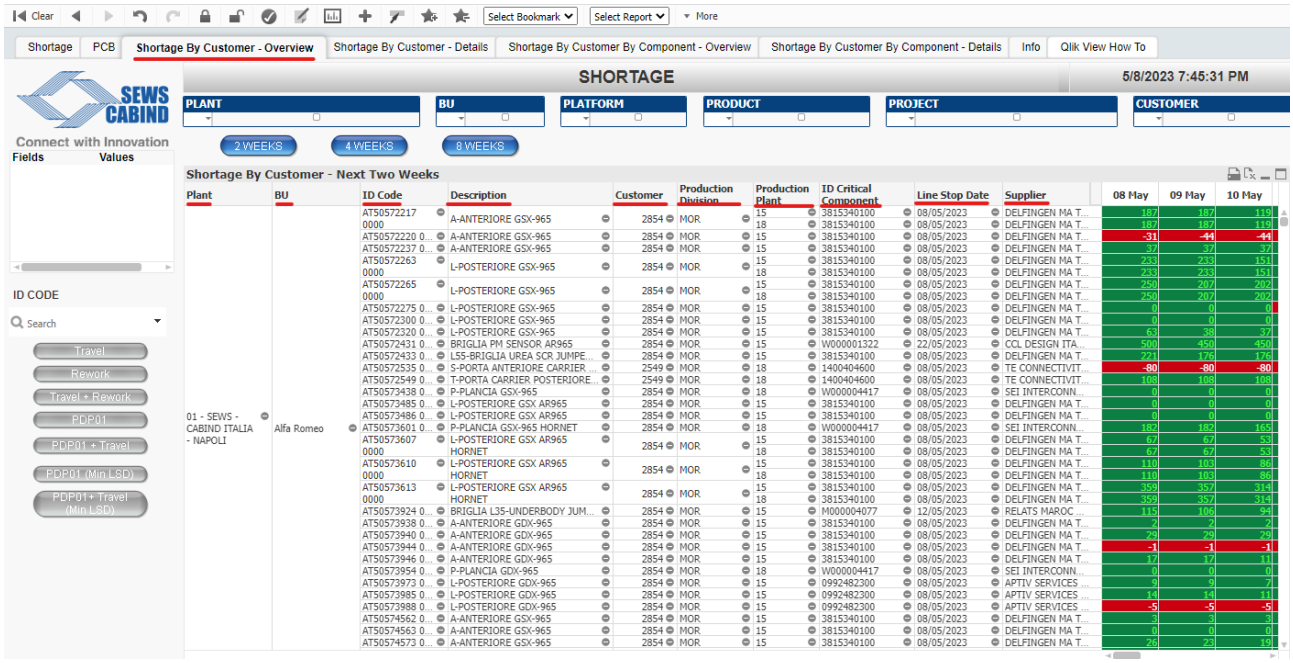

Figura 4. 7 Shortage by customer - Overview

- Plant, in this section by plant it is meant logistic HUB where the finished product is stored (usually they are located in the proximity of important customer to reduce the delivery time).
- BU, represent the car model/project to which the finished product belongs.
- ID code, the pair number of the product.
- Description, brief description of the product.
- Customer, unique ID code associated to the customer.
- Product Division, the division where the product is produced.
- Production Plant, the plant where the product is produced.

- ID Critical Component, taking in consideration all the component by which a finished product is composed, the critical component is the one that will be the first going out of stock.
- Line Stop Date, it is the first day in which we will have shortage of the product.
- Supplier is the supplier of the component.

In this section we analyze from the perspective of the final product. All the final products are listed, and we can see all the related components, in this way is possible to analyze which is the avaiability of every component and consequently understand which one will be the critical component that would determine the shortage. During the covid period it was really common for the customer to contact the supplier to ask details about the current situation. The supplier, in turn, unable to guarantee anything, contacted his supplier to ask for the point of the situation. So it was common to carry out calls with the three supply chain actors present at the same time. In this situation it was essential a tool that guarantee to be able to create different scenarios according to the availability of the suppliers and the needs of the customers. If the supplier was not able to supply all the components, Sews Cabind could in a short time determine which would be the finished product affected and decide which costumers supply first (usually the biggest costumers) or in the case was not able to supply all the products that thee customer requested could draw an alternative scenario in which the customers could pick which product was more urgent and in turn Sews Cabind would use the limited components to satisfy this specific need.

Shortage by customer –Details: in this section (Figure 4.8) is possible to see all the components and calculations that form the output result (stock avaiable).

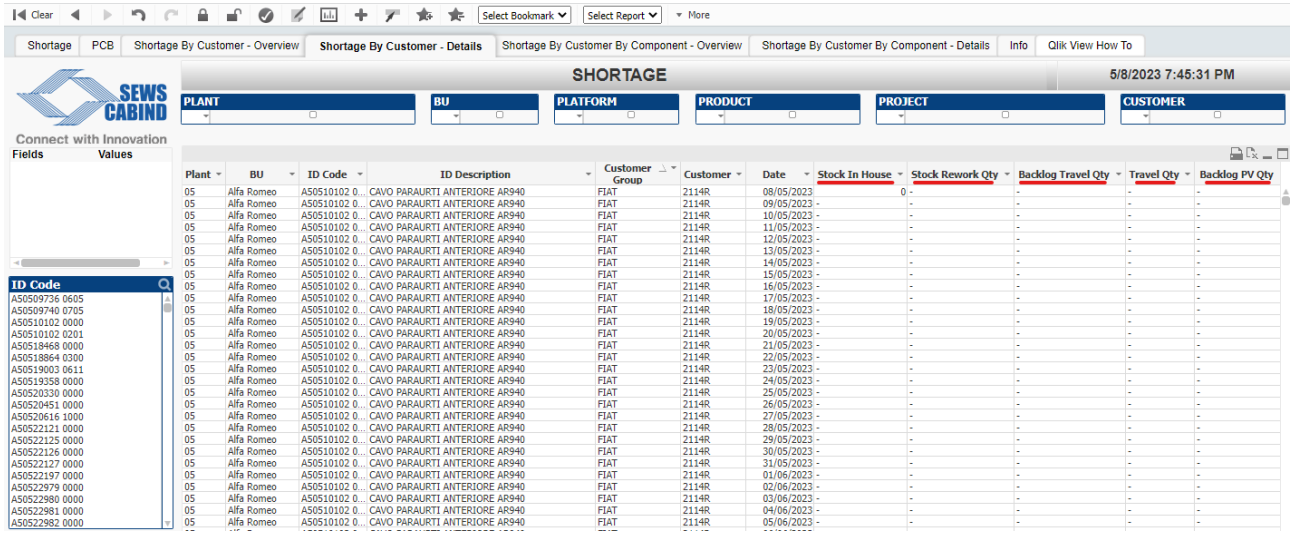

Figura 4. 8 Shortage by Customer - Details

2) Shortage by customer and by component-Overview:

From this dashboard is possible to look at shortage from an inverse perspective. This time we start from the components, and we can see for every component the impact on the final product, in this way is possible to understand which is the critical component and how each of them influence the final product. These two are pretty similar between them, but according to the analysis that must be performed one could be better than the other.

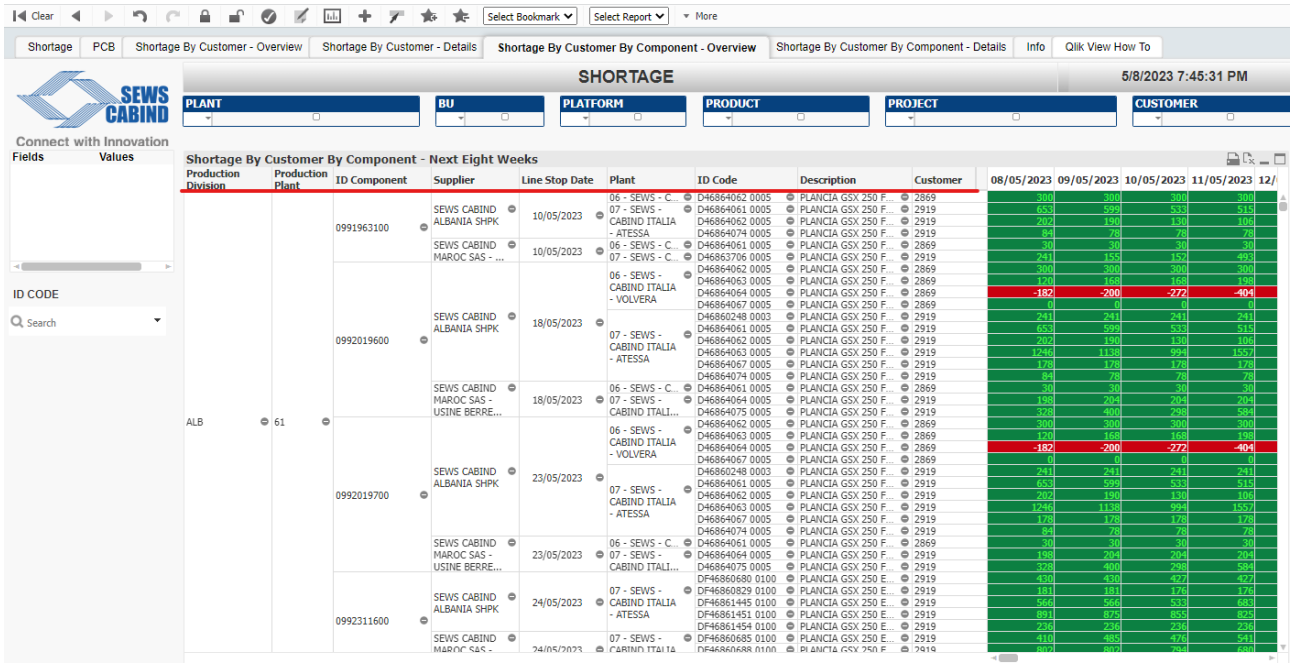

Figura 4. 9 Shortage by customer and by component - Overview

Shortage by customer and by component-Details: (as before)

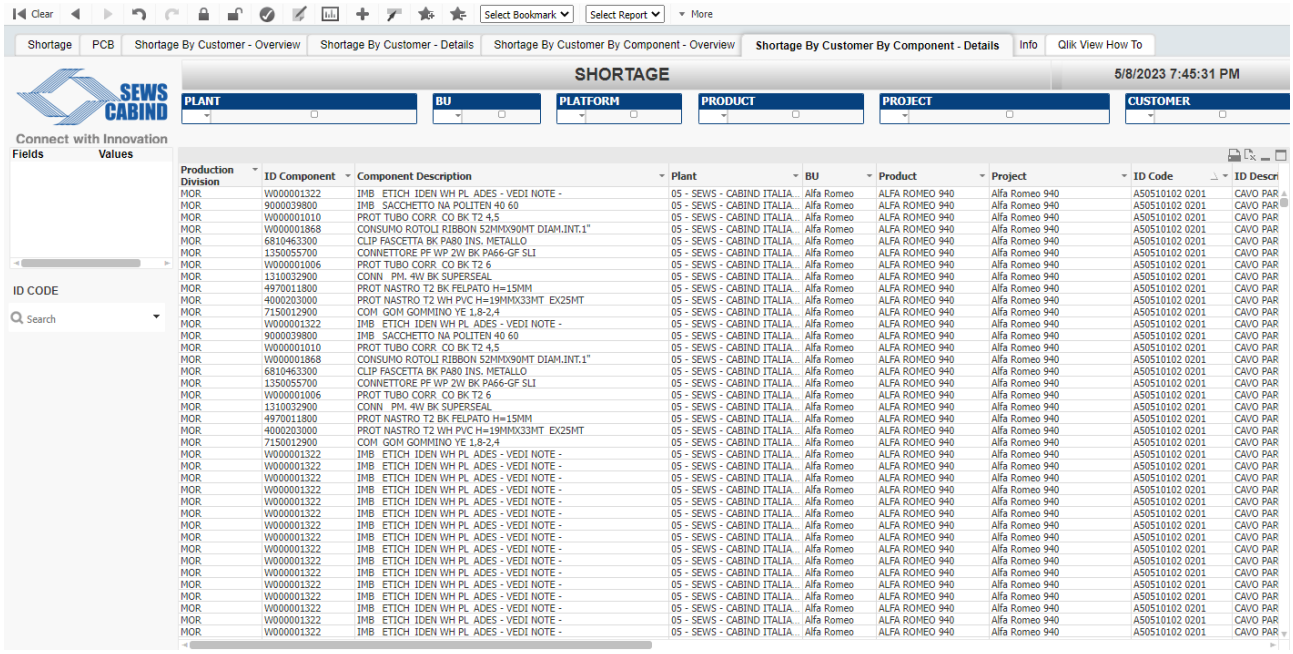

Figura 4. 10 Shortage by customer and by component - Details

CHAPTER 5: IMPACT OF BUSINESS INTELLIGENCE ON BUSINESS'S PERFORMANCES

Several times in this paper, the benefits arising from a proper use of BI tools such as improved data-driven decision-making, improved operational efficiency, risk mitigation and so on, have been mentioned. Although these advantages are quite tangible for who is working in a company (many times during my experience in Sews Cabind, after a BI service interruption many users complained that they could not perform their activities), there is still a lack of quantitative means to prove a clear and quantifiable relation between Business Intelligence adoption and company's performances.[138] Measuring the effects of BI is a widely discussed topic; not least because in itself BI has no value, but creates value as a result of its use, this makes measuring its value very complicated. In this chapter we will describe why it is hard to assess the value of BI and how to evaluate the relation between Business Intelligence adoption and company's performances.

5.1) Quantitative methods

When it comes to financially evaluate something the most common and basic method is the cost-benefit analysis. For the measurement of costs, one possible approach is the "total cost of ownership" (TCO). For its calculation, all the costs associated with the operational resources employed in the activities concerning the BI process and the costs of implementing, deploying, and maintaining the related technology must be summarized, obtaining the TCO. For the measurement of the benefits, the calculations

[138] Ferrari, Antonella.: *Business Intelligence: quale valore?.* [online].
< https://www.zerounoweb.it/analytics/business-intelligence/business-intelligence-quale-valore/>

are more complicated, this because they are intangible and do not generate an effect in financial terms. If we consider specifically the Sews Cabind case, on tangible benefit as mentioned is the time reduction for the activities that BI is supporting. This may be associated with an hour/cost of the user that was performing this activity and that now perform it in a reduced time, but still, it would be not objective indicator since different users have different timing in performing these activities.

Other possible methods for defining the monetary value of an investment include ROI (Return On Investment), NPV (Net Present Value) and Pay Back Period. But, also in these cases, their calculation is a problem because it requires evaluating the cashflows deriving from the investment, which in this case, would be given by the revenue coming from better decision-making, awareness of business processes situation and the other benefits of BI, which is hard to quantify in monetary unit of measure. If we consider the Sews Cabind case, and we try to evaluate how the BI affected the financial performances during the COVID period and the consequent shortage of the automotive sector, we will state that revenue decreased during this period and considering that BI became essential properly in this very period we would wrongly conclude that BI had a negative influence on the company's performances. Obviously, this would be misleading, since there are thousands of other factors influencing the financial indicators of a company.

Moving to more "micro" indicators, one criterion proposed is to measure the effectiveness of BI in terms of the effects generated, by evaluating its contribution to a specific decision or action and then, considering the benefit or harm to the company that resulted. Measurable benefits are identified related to decisions regarding: avoiding unnecessary costs (not facing investments in the development of a product that, from BI analysis carried out, has been found not to match consumer tastes); generating revenue increases (satisfactory up-selling campaigns based on the analysis of the customer base); optimizing the allocation of resources and thus maximizing investments toward higher profitability goals; and improving performance (greater knowledge of the customer, closer relationship and consequent increase in customer

satisfaction and loyalty). For proper measurement, however, it should be demonstrated that these results are achievable only through the use of BI. Taking as an example the Shortage application, it allows monitoring the available stock, in order to give awareness of possible upcoming shortage events. Hence, one indicator to rely on may be penalties paid to customers for not delivering products on time. BI gives you awareness of this kind of events but are users that one time recognized the problem have the task to solve it. So, there will be cases where users, one time recognized the problem, solved it and other cases where this was not possible, in both cases BI performed the same activity.

5.2) Qualitative methods

An alternative approach to detect the effects of BI more accurately is through qualitative analysis. Qualitative research is used to understand how people experience the subject of research.[139] In this case, it is based on the concept of the decision-maker's perceived usefulness and satisfaction (how much did his confidence in his decision-making ability improve in relation of having more and more reliable information as a result of BI? How much did his satisfaction related to the acquisition of greater insight and speed of action enabled by BI increase?). In the following paragraph some of the literature existing about this topic will be presented, all of them is based on surveys to management and employees of companies that adopt BI systems, and then apply advanced statistical models to extract insight and draw conclusions.

[139] Bhandari, Pritha.: *What Is Qualitative Research? | Methods & Examples*. [online]. <https://www.scribbr.com/methodology/qualitative-research/>

5.3) Literature

One example of analysis of the relation between BI and company's performance is given from "The Impact of Business Intelligence on Corporate Performance Management"[140]. The purpose of the article was to propose a model identifying and linking Corporate Performance Management (CPM) and Business Intelligence. BI and CPM were considered as the construct of different features (data quality, pre-defined data analysis, technical data, ... for BI, and business processes, organizational processes, … for CPM) and in turn also features were composed by different items. The study was conducted by analysing responses from an industry survey to identify the most critical factors that influence BI and CPM. In order to understand the relationships between the identified factors, statistical analysis methods including Partial Least Squares – Structured Equation Modelling (PLS-SEM) were used. The results delivered statistical evidence of a positive relationship between BI and CPM in an organisation across key factors identified through the literature review and factor analysis.

Another similar study was conducted in "The impact of Business Intelligence on the quality of decision making – a mediation model"[141]. This paper investigates the direct and indirect effects of BI management quality on the quality of managerial decision making using PLS analysis of survey responses of senior IT managers in Australia. Also in this case, the results confirmed that BI management quality has positive direct and/or indirect effects on data quality, information quality, and the scope of BI solutions.

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[140] Hartl, Karin et.al.: *The Impact of Business Intelligence on Corporate Performance Management*. [online]. <https://www.researchgate.net/publication/301281313_The_Impact_of_Business_Intelligence_on_Corporate_Performance_Management>

[141] Wieder, Bernhard.: *The Impact of Business Intelligence on the Quality of Decision Making – A Mediation Model*. [online]. <https://www.sciencedirect.com/science/article/pii/S1877050915027349?ref=pdf_download&fr=RR-2&rr=7dcbcfc92e15baca>

In conclusion, there are numerous suggested approaches to assessing the actual contribution of Business Intelligence to business value creation, yet we are still a long way from identifying a path toward their useful systematization or their quantifiable value.

CONCLUSION

Before the adoption of the Qlikview software, all the operations, shown in chapter four, concerning the Shortage application, were carried out manually. This implied an incredible time commitment, and in addition the resulting process was really inefficient. In fact, as you can well imagine, in Sews Cabind the amount of part numbers or finished products daily managed is quite considerable, consequently the 100% monitoring of these products was almost impossible to carry out. Monitoring and control operations routinely took place for the products of the most important projects and for the tensest flows of the company, alternatively, these operations were carried out after receiving notification of shipment delays from suppliers. Eventually, ex-post actions were taken, once the delay had already occurred. The company, like many others in the industry, as we saw when looking at the first general 'shortage' dashboard, was already timidly beginning to move in this direction, adopting first simple BI application models, to let's say 'test the waters'. The advent of COVID and the related crisis of the industry forced companies to accelerate this process. Many of them started to invest heavily and put all their resources into adopting this type of solutions as quickly as possible. In the case of Sews Cabind, the choice of a software such as QlikView was mainly due to the various characteristic features that this product possesses, but also to the fact that it could rely on a large network of re-sellers and assistance near to its geographic area. A couple of years on from the adoption of this technology, it is clear that the operation was a success, even considering the cost of the investment. Logistics users can fully monitor processes, identifying critical situations well in advance and giving BU users time to adopt corrective actions, the overall process became smoother and efficient, with the consequence of a great time savings for the logistics operators, who can dedicate to other activities, and an increase of the service level to the customers. The success is due also to the great collaboration between the developers and the user of the application, and this process is still going

on. Periodically users suggest the implementation of new features and developers and business analysts evaluate their feasibility. These conclusions are based on qualitative personal evaluations and personal experience as a BI user.

During the first chapter showed some of the new trends of BI, just to give an idea of what we are talking about, we will show how they would change this actual solution. Artificial Intelligence (AI) and Machine Learning (ML) could be used to show to users just the critical part numbers, specifying the parameters and rules that make a part number critical thanks to AI and ML, final users would not need to search for them (even if now this work can be facilitated by the use of filters).

Through a combination between the previous and Natural Language Processing (NLP) and Conversational BI, users would just need to write or vocally say, which are the part number that they would need to analyse. And last with the help of augmented reality (AR) and virtual reality (VR) users would also be able to see them!

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