POLITECNICO DI TORINO

Collegio di Ingegneria Gestionale e della Produzione
Corso di Laurea Magistrale in Management Engineering

Application of the Business Intelligence to a management control system: case study

Relatore:
Prof. Luca Mastrogiacomo

Candidato:
Giulia Strambi

A.A 2024/2025

Index images:

Index Table:

Abstract

Businesses are constantly seeking new ways to enhance efficiency and make smarter decisions. This thesis explores how business intelligence can help organizations optimize their processes by turning raw data into meaningful insights.

The initial section of this research delves into the evolution of business intelligence, tracing its journey from the early days of database management systems to the emergence of more sophisticated decision support systems and online analytical processing. It also underscores the transformative role of big data, illustrating how businesses can harness vast amounts of information to refine their strategic decision-making processes.

A central focus of the thesis is the BOARD platform, an enterprise performance management tool designed to integrate data analysis, reporting, and visualization seamlessly. The study examines its architecture in detail, highlighting how multidimensional data models and interactive dashboards empower decision-makers with real-time insights, enhancing their ability to make informed and timely choices.

The research is based on a real-world case study conducted with Bios Management S.r.l., a consulting firm specializing in business process optimization through business intelligence solutions. The project aimed to tackle common corporate challenges such as data fragmentation, slow reporting processes, and limited integration between different information systems like ERP, CRM, and Excel. By implementing a custom reporting model within BOARD, the company was able to streamline operations, improve data accessibility, and enhance strategic decision-making.

The results demonstrate the practical benefits of business intelligence, including faster reporting cycles, improved performance monitoring, and more effective management decisions. The thesis concludes with a critical analysis of the project's impact and potential future developments in business intelligence and data-driven decision-making.

1 Introduction

In today's business landscape, companies are constantly seeking new strategies to improve efficiency and sustainability in their operations. Business Intelligence (BI) has emerged as a crucial tool for enhancing decision-making by integrating and analyzing business data. Its application in Quality Engineering is particularly significant, as it enables companies to optimize processes, improve quality control, and make data-driven decisions.

This thesis focuses on the implementation of Business Intelligence and its role in operational performance monitoring. The primary objective is to demonstrate how BI solutions can enhance management control quality and support compliance with industry standards.

The research is based on a real case study, where the adoption of the BOARD platform has helped optimize corporate decision-making, particularly in human resource management and financial planning. Through this study, the challenges encountered, the methods applied, and the benefits of integrating BI into business processes will be analyzed.

To fully understand the role of Business Intelligence and its impact, the thesis is structured into several sections:

1. Foundations of Business Intelligence
    - Overview of BI, its definition, historical evolution, and core technologies such as Database Management Systems (DBMS), Decision Support Systems (DSS), and Executive Information Systems (EIS).
2. Structure of a BI Solution
    - Analysis of the key components of a BI system, from data collection and integration to advanced analytics using tools such as OLAP, Data Mining, and Data Visualization.

3. Impact of BI and Big Data on Business Decision-Making
    - Evaluation of how BI influences business performance management, including Corporate Performance Management (CPM) and Management Control Systems (MCS), with a focus on reporting and KPI tracking.
4. Case Study: Implementation of BOARD in Bios Management S.r.l.
    - Examination of the adoption process and the results achieved in improving management control and strategic planning.
5. Comparison of BI Software Solutions
    - Comparative analysis of BOARD against other BI tools in terms of functionality, performance, and adaptability to business needs.
6. Conclusions and Future Developments
    - Summary of key findings, analysis of research limitations, and proposals for future applications and improvements in Business Intelligence.

The goal of this thesis is to demonstrate how a well-implemented BI solution can significantly enhance business management by increasing data transparency and supporting more effective decision-making. The conclusions will provide valuable insights for companies looking to adopt similar solutions, as well as suggest potential future developments in Business Intelligence and data analytics.

2 Fundamentals of Business Intelligence

2.1 Definition

Most companies gather vast amounts of data daily from various sources. To effectively utilize this data and extract meaningful insights, it's essential to implement a Business Intelligence system to support decision-making.

Business intelligence is defined as a "decision-making process supported by the integration and analysis of an organization's data sources" (1). It provides useful intuitions to facilitate reporting, predictive analysis, data mining, and data visualization.

Nowadays, organizations are facing numerous challenges due to the competitive and ever-changing environment. In this scenario, advanced technologies and tools play a crucial role in processing information and supporting effective decision-making at the organizational level.

The decision-making process can be divided into three main parts, which are:

1. Access, collection, and refinement of required data and information
2. Processing, analyzing, and drawing conclusions based on knowledge
3. Applying the result and monitoring the consequences of its implementation

In each of the above cases, traditional organizations that do not use business intelligence face problems that often arise due to the volume of data, the complexity of analytics, and the inability to track the consequences of decisions.

Through the smart use of information, business intelligence improves business planning and the budgeting process through data-driven decisions based on historical data and trends identified through analysis.

The main advantage is to improve the timeliness and quality of information used in the decision-making process. This ensures that information is delivered at the right moment, in the right place, and in the suitable format to effectively assist decision-makers. In every case, employing business intelligence is considered a proactive strategy.

The capacity to adapt to the unique demands of a specific sector or business function enables a vertical approach. This strategy enhances the effectiveness and utility of solutions, ensuring that the system's offerings are well-aligned with the industry's challenges and requirements Additionally, it allows Business Intelligence to adapt flexibly to changes without completely reinventing the system. (2)

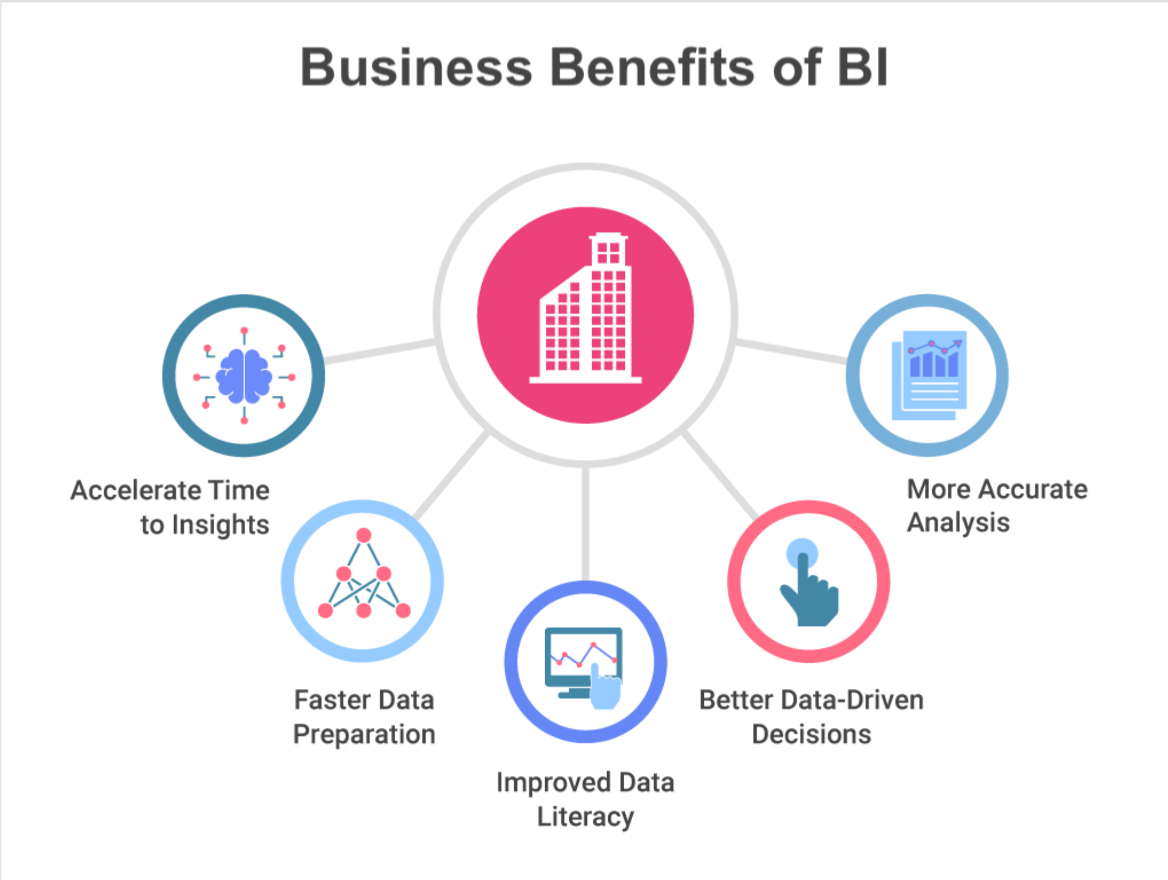

Image 1- Business Benefits of BI

2.2 History and Development of BI

In the early years of the 1960s, the concept of Business Intelligence began to take place with the advent of computer technology. Thanks to Hans Peter Luhn, a German American computer scientist who worked for IBM, we have made significant advancements in the field.

He was one of the first to recognize the challenges posed by the growth of organizations due to the increase in specialization and sectionalization, which created new barriers to the flow of information (3) and for this reason, in 1958, the expression "Business Intelligence" was coined for the first time in the article "A Business Intelligence System."

In this work, Luhn described an automated system that can transmit information across various sectors, including scientific, industrial, and governmental organizations, which are key players in the third industrial revolution.

In his definition of "business intelligence," the term "business" refers to "a set of activities conducted for various purposes, including science, technology, commerce, industry, law, government, and defense". The term "intelligence" is defined as "the ability to understand the relationships between presented facts in a way that guides actions toward a desired goal."(3)

His vision aims to create an automated system within the organization that could distribute information at all levels. This system would ensure that data flows effectively to the relevant departments, enhancing communication and supporting decision-making throughout the organization.

Luhn suggested that the use of data-processing machines could effectively accomplish auto-abstracting and auto-encoding of documents, as well as create interest profiles for each "action point" within an organization.

The initial process involves identifying keywords to increase the document's summary, ensuring it accurately reflects the key themes and topics. Following this, an encoding process automatically assigns codes or labels to specific concepts and categories within the document. This method facilitates the identification of action points that highlight the main themes of interest, allowing for precise sharing of information with those who need it. (3)

2.2.1 Data management system DBMS

To understand the concept and evolution of Business Intelligence (BI), it is essential to mention tools that can store vast amounts of data.

In 1956, the International Business Machines Corporation (IBM) reached a significant milestone in storage technology with the introduction of the first hard disk and floppy disk. These groundbreaking innovations enabled businesses to transition from paper-based storage methods to more efficient and expansive digital solutions. The RAMAC, recognized as the first hard disk system, boasted a storage capacity of 5 megabytes of data.

The floppy disk made it possible to easily load software and updates onto mainframe computers and quickly became the most widely used storage medium for small systems. (4)

The true revolution in data storage and management came in the 1960s. This decade saw significant advancements in technology, particularly with the development of Database Management Systems (DBMS), thanks to Charles W. Bachman.

This architecture is designed for autonomous operation, the main functionalities achieved by a DBMS are:

- Administration tasks include change management, performance monitoring, security, and backup and recovery. Most database management systems also handle automated rollbacks and restarts, as well as logging and auditing of activities in both the databases and the applications that access them. (5)
- Storage A 9DBMS efficiently stores and retrieves data in tables, rows, and columns. (5)
- Concurrency control ensures that transactions are executed in a controlled manner to prevent data corruption or inconsistencies. (5)

- A centralized view allows users to access data from multiple locations in a controlled manner. A DBMS can limit what data end users see and how they view it, providing various views of a single database schema. (5)
- Data manipulation. DBMS maintains data integrity and consistency by allowing users to insert, update, delete, and modify data within a database. (5)
- Data independence. A Database Management System (DBMS) provides both logical and physical data independence, allowing users and applications to avoid concerns about where data is stored or changes in its physical structure. As long as developers use the application programming interface (API) provided by the DBMS, they won't need to modify their programs, even if changes are made to the database. (5)

There are several types of Database Management System (DBMS) architectures, each designed to meet specific usage requirements.

In a 1-Tier Architecture, the database is directly accessible to the user, allowing for direct interaction with the relational database to execute operations.

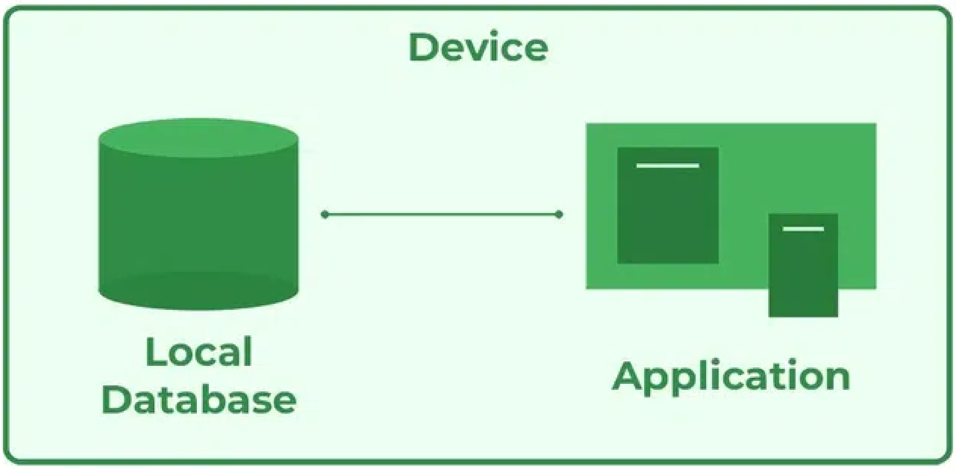

Image 2- DBMS 1 Tier Architecture

The 2-Tier Architecture follows a client-server model in which the client application communicates directly with the database server through APIs such as ODBC and JDBC. In this setup, the server is responsible for query processing and transaction management, while the client focuses on the design of the user interface.

Image 3- DBMS 2-Tier Architecture

In a 3-Tier Architecture, an additional layer is introduced between the client and the server. Instead of communicating directly with the database server, the client interacts with an application server. This application server then communicates with the database system, where query processing and transaction management are carried out.

This last architecture is particularly well-suited for managing modern and large database systems. (5)

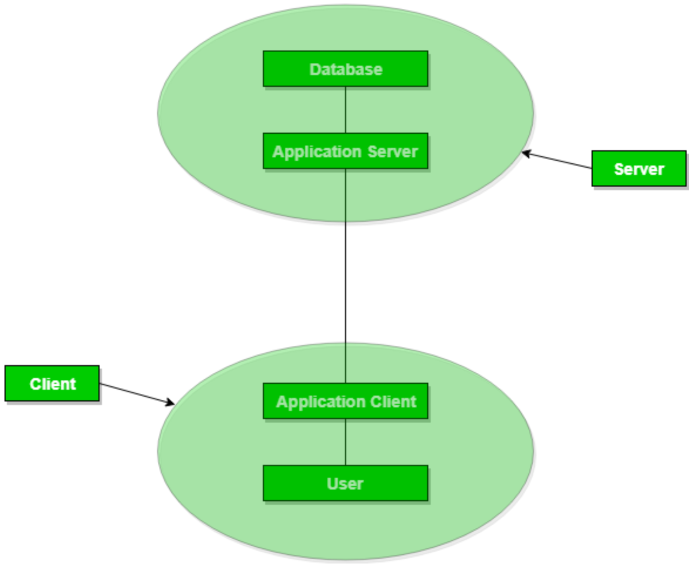

Image 4- DBMS 3-Tier Architecture

Over the years, various Database Management Systems (DBMS) have been implemented to meet diverse data management needs.
The first type of DBMS developed was the hierarchical model, where data is structured in a tree format, the classical parent/child relationships, limiting possible connections to "one-to-many." This structure was particularly suited for applications requiring stable, predictable hierarchies. One of the first hierarchical data management systems that significantly impacted the industry was IMS (Information Management System), developed by IBM in 1966 to catalog components for the Apollo spacecraft. Initially, IMS was primarily adopted by the airline and reservation industries, but its applications quickly expanded to various fields, including insurance and finance. Over time, it evolved into one of the leading database management systems for business applications. Additionally, IMS helped establish database management system standards and influenced subsequent database solutions' development. (6)

In 1969, the Network data model, known as Integrated Data Store (IDS), was implemented to overcome the limitations imposed by the hierarchical model. This model was able to overcome the limitations of the one-to-many relationship typical of the hierarchical model and introduce databases characterized by "many-to-many" relationships. However, this model was outclassed due to the complexity of managing numerous growing connections as the data increased, leaving space for relational databases, which are more flexible and user-friendly.

In the relational model, like Oracle Database or Microsoft SQL Server, records are connected through specific fields called connectors or pointers. The core of this system is the concept of linking records. Each record in a table has a primary key, which acts as a unique identifier for each row. This key can either be one of the existing data points or an additional field created specifically for this purpose, commonly known as an Object Identifier (OID). (6)
The main programming language for managing this type of database is SQL (Structured Query Language), which allows users to query and manage databases using components called queries.
In the late 1980s, object-oriented databases (OODBMS) began to be developed due to the diffusion of object-oriented programming languages, such as C++ and Java. In

these databases, each record not only contains data but also includes instructions and operations that can be performed on that data. The source code comprises virtual objects that represent the attributes and behaviors of real-world objects or concepts. (6)

2.2.2 Decision Support System (DSS)

Having reviewed the historical development of Database Management Systems (DBMS), we can now turn to the origins and advancement of Decision Support Systems (DSS). Which broadly includes today's Business Intelligence applications and aligns with the focus of this study. This progression from DBMS to DSS highlights the expanding role of data in supporting organizational decision-making processes.

The concept of Decision Support Systems (DSS) is attributed to Michael S. Scott Morton, a researcher at the Massachusetts Institute of Technology (MIT). Scott Morton introduced the term in the early 1970s, specifically in his 1971 work on "Management Decision Systems," which discussed the potential for interactive, computer-based systems to support management decision-making.
This marked the beginning of DSS, leading to the development of more sophisticated models and tools that paved the way for modern Business Intelligence applications.

To define a Decision Support System (DSS) in simple terms, we can say that these are software systems that provide users, specifically decision-makers, with various data analysis functionalities. They leverage mathematical and statistical machine learning models to offer insights quickly, interactively, and easily, thereby enhancing the efficiency and effectiveness of the decision-making process. (7)
In the beginning, Morton developed a well-known matrix that illustrates how decision-making processes vary across different management levels and organizational structures. As individuals move from operational management to executive positions, the nature of their decision-making evolves significantly.
Decision-making starts with structured decisions, which can be clearly defined by specific rules or algorithms. These decisions are easy to repeat and often suitable for automation. The process then evolves into semi-structured decisions and eventually to unstructured decisions. Unstructured conclusions do not have predefined procedures or rules, making them challenging to program. They are marked by varying decision-making processes and unclear data requirements, often requiring analysis through various models. These types of decisions are less frequent and are typically made by top management, placing them at the top of the decision-making hierarchy.

Structured decisions usually rely on known information and do not require specialized skills, positioning them at the foundational level of the decision-making process. This framework illustrates that higher management levels primarily handle complex, unstructured issues, which demand greater judgment and less reliance on established processes. In contrast, semi-structured decisions incorporate both programmable and non-programmable elements. These decisions are often linked to management control and reside in the middle tier of the decision-making hierarchy. (9)(8)

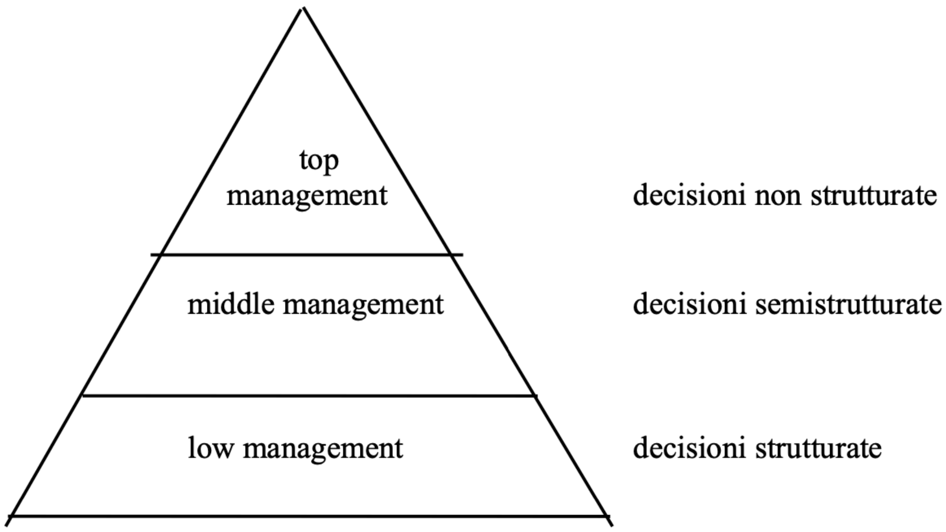

Image 5 - DSS

From an application perspective, developing a decision support system generally involves four main phases:

- Intelligent: in this stage, the real problem to be addressed is identified, and useful data are listed.
- Design: analytical experiments are conducted, leading to the construction of the analytical model (often more than one), from which various possible solutions are generated.
- Choice: Identify the optimal one(s) for the business.
- Implementation

2.2.3 Executive Information System (EIS)

In the late 1970s, the Executive Information System (EIS) was developed as a specialized form of decision support system (DSS) aimed at assisting upper management in the decision-making process. This distinguishes it from the more commonly used DSS employed by middle and lower levels of management.

The EIS is designed to provide essential and up-to-date information to streamline decision-making. It is also valuable for identifying potential problems or opportunities. The system prioritizes a user-friendly interface that presents data in an easily understandable manner. [10]

An EIS has four main components:

- Hardware: An Executive Information System (EIS) environment focuses on the needs of executives, which must be considered. The key components include input data entry devices, the central processing unit (CPU), data storage, and output devices.

- Software: An EIS's software should be able to integrate all available data into integrated results. The text base primarily refers to documents representing the most common form of text. The database includes heterogeneous databases hosted on various computing platforms, whether vendor-specific or open-source, allowing executives to access internal and external data. The graphic base transforms large volumes of text and statistics into visual information useful to executives; typical types of graphics include time series charts, scatter diagrams, maps, animated graphics, sequences, and comparative graphs such as bar charts. Finally, the model base includes EIS models for routine and specialized quantitative analyses, including statistical and financial analyses.

- User Interface: This is the main component and the place where the interaction between humans and machines occurs. There are several types available to the

EIS structure, such as scheduled reports, questions/answers, menu-driven, command language, natural language, and input/output.

- Telecommunications: it is a central capability since the ability to transmit data from one place to another has become crucial for establishing a reliable network.[10]

The future of executive information systems will no longer be limited to mainframe computer systems. This shift enables executives to avoid learning multiple operating systems and significantly reduces implementation costs for companies. By leveraging existing software applications, executives can also elude the need to learn a new or specialized language for the EIS package. [10]

2.3 Business Intelligence & Analytics

After examining the major revolutions that have characterized and changed the technological world, from the development of the first information systems in the 1970s to the advent of Artificial Intelligence, we can place the focus of this work on business intelligence systems within this broad and complex context known as the digital revolution.

Based on the events outlined earlier, Business Intelligence (BI) can be divided into three main evolutionary stages, which are closely linked to the technologies and applications employed. As highlighted in the article "Business Intelligence and Analytics: From Big Data to Big Impact," published in MIS Quarterly, an academic journal focused on Management Information Systems, Figure 6 illustrates these distinctions (11):

- BI&A 1.0: Represents the initial phase of Business Intelligence, where technologies and applications primarily focus on structured data and rely on relational database management systems. The focus is mainly on historical data analysis using tools such as OLAP, querying, and the creation of dashboards and reports.

- BI&A 2.0: Represents an evolution that incorporates emerging technologies, such as the Web, starting in the 2000s. It includes the analysis of unstructured data, such as web analytics, social media analytics, and text mining.

- BI&A 3.0: Highlights the growing importance of mobile devices, the Internet of Things (IoT), and other emerging technologies such as sensors.

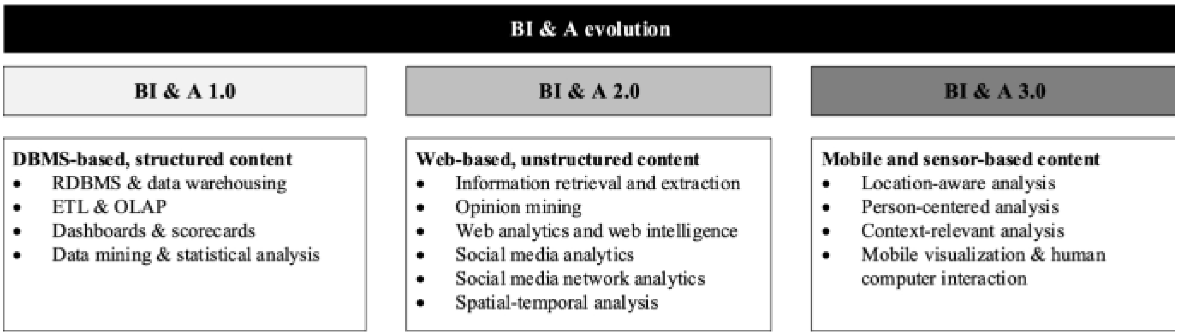

Image 6 - BI & Analytics Evolution

3 Business Intelligence solution

3.1 Knowledge Discovery from Data (KDD)

The process of extracting knowledge, commonly known as Knowledge Discovery from Data (KDD), aims to transform data into valuable insights through specific steps. This process allows for the formulation of precise conclusions. For instance, knowledge gained from analyzing a medical database could be published in a medical journal. (12)

In their seminal paper from 1996, Fayyad et al. introduced the concept of KDD The model comprises five steps, which lead from raw data to actionable knowledge and insights which are of immediate value to the user. The whole process is shown in Fig. 7. (13)

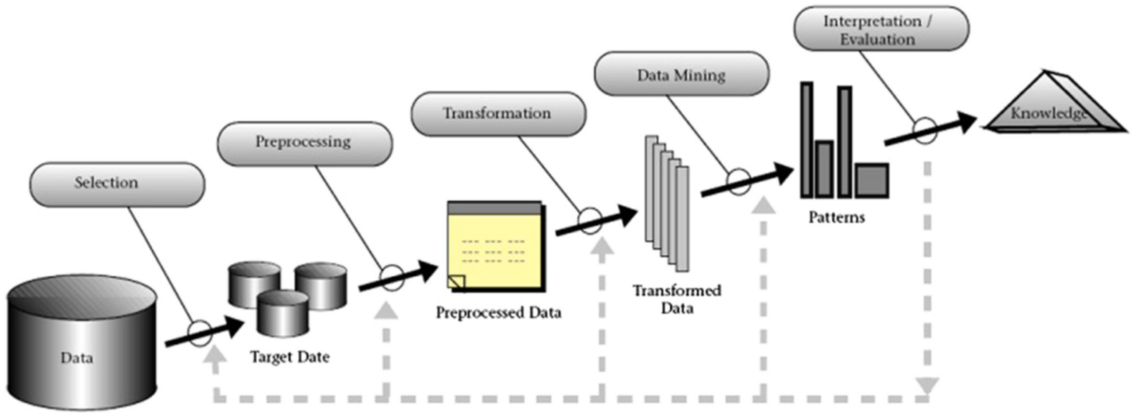

Image 7 - An overview of the steps that compose the KDD process

The first step is to develop an understanding of the application domain, capture relevant prior knowledge, and identify the data mining goals from the end user's perspective. Next, the selected data must be processed to facilitate subsequent analysis. Typical actions in this step include handling missing values, identifying and potentially correcting noise and errors in the data, and resolving conflicts for data sourced from different origins.

Once the data is converted into a format that can be easily analyzed—typically as feature vectors—it enhances the performance of data mining algorithms and prepares the data to be readable by end users. (13)

3.2 Structure of a BI solution

A Business Intelligence (BI) solution is an integrated system that transforms raw data into meaningful insights to guide strategic and operational decisions within an organization. In today's data-driven world, organizations generate massive amounts of information from various sources, including transactional systems, social media, IoT devices, and third-party APIs. To join the power of this data, a well-structured BI solution ensures that it is effectively collected, processed, stored, analyzed, and presented in ways that enable stakeholders to make informed decisions.

The main steps to generate such a type of solution are shown in Figure 8. Together, these components create a cohesive system that empowers organizations to harness the power of their data. A well-designed BI solution helps in understanding past and current performance and enables proactive decision-making and long-term planning, giving organizations a significant competitive advantage in an increasingly data-centric world.

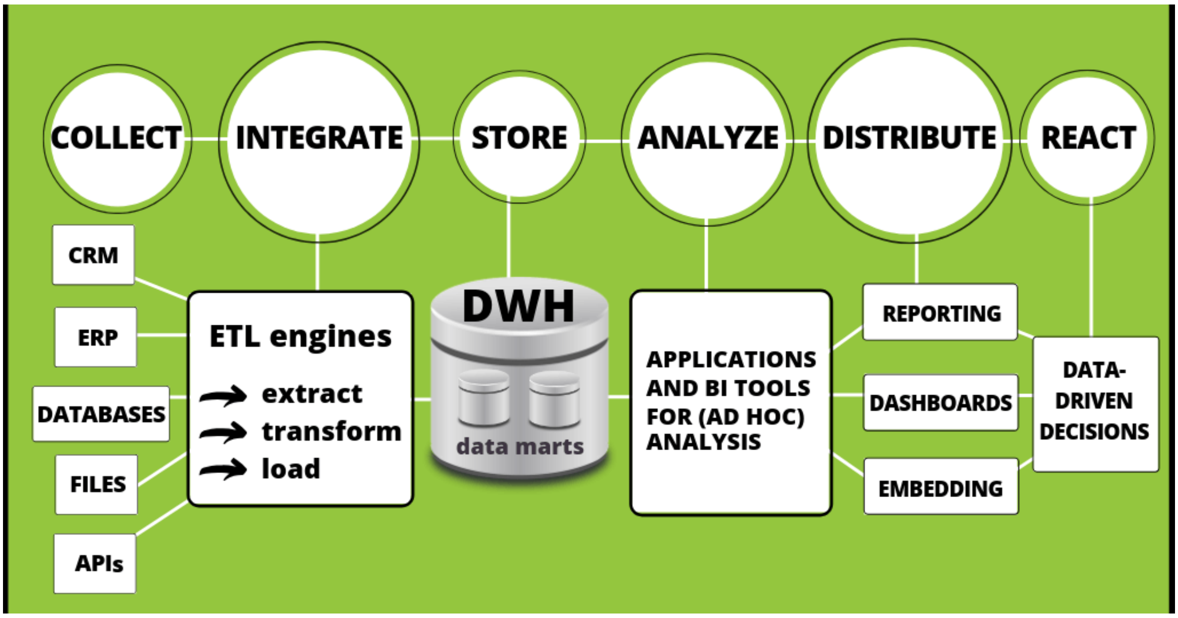

Image 8 – Architecture of a BI solution

3.2.1 Data Collection

The BI (Business Intelligence) system acquires data from multiple sources, which, while not part of the main environment, are essential for feeding the BI solution and forming the foundation of the entire architecture. (14)

These primary sources can be categorized into two types:

- Internal Information Systems (or DBMS): This category includes systems such as Supply Chain Management (SCM), Customer Relationship Management (CRM), and Enterprise Resource Planning (ERP).

- External Sources: this includes data obtained from third-party providers, such as web sources or customer research. (15)

The data is typically processed in various formats, with SAP tables being the most common. However, it can also be presented in other formats, such as Excel, TXT, or CSV. (14)

3.2.2 Data Integration

Data integration (DI) is "the process of combining, merging, or joining data together, to make what were distinct, multiple data objects, into a single, unified data object." (16) (17).

Data integration plays a pivotal role in any organization because it allows it to integrate data from various sources, which are ideally unstructured, semi-structured, or structured, and enables organizations to harness the value of their business and the data to be completely utilized by the users (18).

The steps that these types of tools use to collect and process data are (19):

- Extract: in this phase, data recovery from the different types of sources occurs thanks to data connectors or adapters to reduce the quantity of data and improve the quality of the information that is needed.
- Transformation: is the process of converting and mapping data from one format or structure to another to make it usable and compatible with target systems

and business rules. It involves manipulating and reorganizing data to meet the specific requirements of applications or business processes, starting with data cleaning, this includes removing duplicates, correcting erroneous data, and addressing missing values or outliers.

It addresses the challenges posed by heterogeneous data from different sources, transforming it into a standardized and consistent format.

- Extraction: After the data has been transformed and mapped appropriately, they are loaded into the target destination, usually a Datawarehouse, where they can be easily accessible for analysis and report generation. The majority of data integration tools provide several types of data loading, including real-time data streaming and batch processing.

This process is also known as ETL (Extract, Transform, Load), and often, the three phases are run in parallel to save time. For example, while data is being extracted, a transformation process could be working on data already received and preparing it for loading, and a loading process can begin working on the prepared data rather than waiting for the entire extraction process to complete. (20)

Sometimes, in certain systems, a temporary "Staging Area" area is used before loading data into the Data Warehouse (DWH). This intermediary space facilitates the execution of the ETL (Extract, Transform, Load) process, enabling the integration of data from various sources before it is consolidated into the Data Warehouse.

The presence of this area sometimes referred to as the Operational Data Store (ODS), supports complex operations for transforming and cleaning data while it remains in a format close to the OLTP (Online Transaction Processing) representation. However, its use increases redundancy and requires additional storage space for data. (21)

3.2.3 Data Store

Once the data has been integrated and consolidated with the ETL process, their processing takes place by loading into the Datastore, also called Data Warehouse (DW).

Data Warehouses are a subject-oriented, integrated, time-variant, non-volatile collection of data that is used primarily in organizational decision-making (Inmon,1996) for decision support within a company. (22)

Data warehouses, which are designed for decision support, are kept separate from operational databases that are organized around various applications within a business. While operational databases typically focus on recent data due to the nature of most transactions, data warehouses enable analysis of historical data from past years (data history) as well as projections for future years, including budgets and forecasts.

The need for separate systems lies above all in the different performances that they must provide, in the different objectives, and consequently in the different volumes.

The data present within the DWH are characterized by (23):

- Subject-oriented: data are focused on concepts of interest to the company, such as sales, products, or customers.
- Integrated: all data must be combined and integrated, even if it comes from different sources.
- Time variant: Data warehouse stores historical data.
- Non-volatile: after data is loaded, users cannot change or update the data.

There are different methodologies for designing a Data Warehouse (DW), typically categorized into two main approaches: (21)

- Top-Down Approach: This method begins with a comprehensive, enterprise-wide perspective, progressively moving toward detailed implementation. The process starts with defining requirements and creating a conceptual model, then transitioning into a physical model. While this approach ensures greater alignment with organizational objectives, it involves higher complexity during the design phase.

- Bottom-Up Approach: In this strategy, the design starts with operational data, focusing on building smaller, specific data marts tailored to individual business areas. Over time, these data marts are integrated incrementally, forming a complete Data Warehouse. This approach is more iterative and allows for quicker implementation in specific areas, but it may require adjustments to achieve full enterprise alignment.

These approaches represent distinct philosophies in DW design, balancing immediate needs against long-term scalability and integration.

The architecture of a data warehouse can be divided into four different typologies based on the number of historicizations that occur and business needs. (21)

- One-Level Architecture: This design has no clear separation between the data sources and the Data Warehouse (DWH). The primary goal is to minimize data redundancy. To achieve this, the DWH is virtual, created dynamically through an intermediate processing layer that simulates a multidimensional view of the data.
- Two-Level Architecture: This approach introduces a distinction between the data source layer and the Data Warehouse. ETL (Extract, Transform, Load) processes are used to bridge these layers. Supporting the DWH, there may be specific data marts designed for individual business areas or metadata that provides detailed information about the input data.
- Three-Level Architecture: This model incorporates a staging area, an intermediate storage space between the data sources and the Data Warehouse. This staging area helps optimize ETL operations by temporarily storing data for processing. However, this design increases data redundancy, as intermediate storage requires additional space.

- Data Mart: or localized data warehouses are small-sized DW, typically created by individual departments or divisions to facilitate their decision support activities. A data mart can be created for specific products or functions, like customer management, marketing, finance, etc. One of the purposes of building a data mart is to get a prototype as soon as possible without waiting for a larger corporate data warehouse because it's small and easy to develop. However, after having several data marts, organizations face operational difficulties in using them in an overall corporate data warehouse strategy because individual data marts are not consistent with each other. (22)

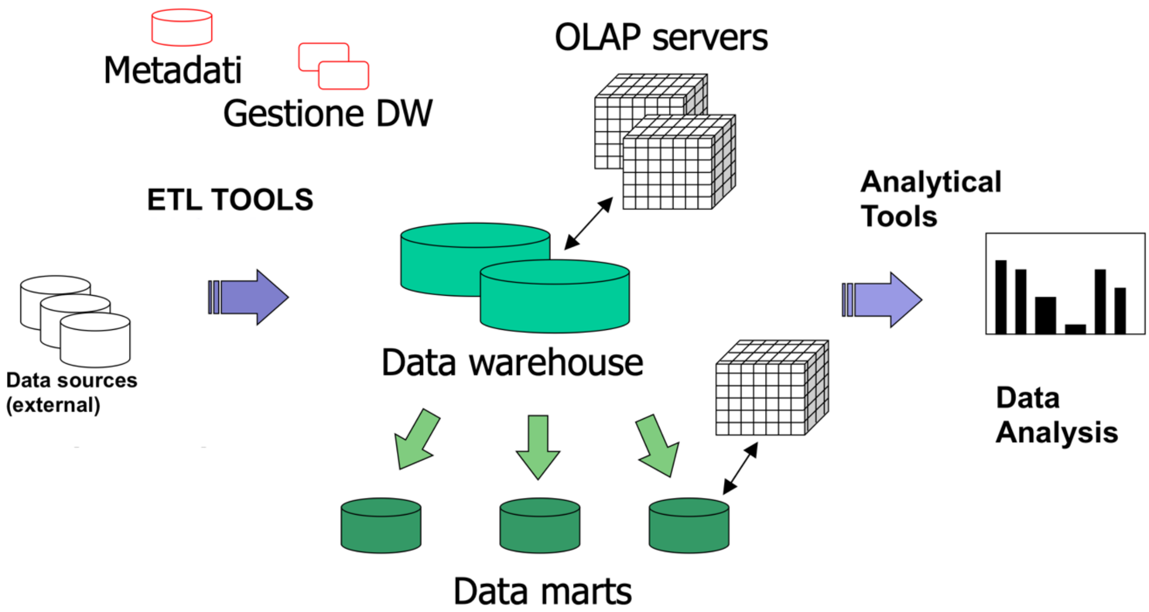

Image 9 – Building Blocks of a Data Warehouse

3.2.3.1 Multidimensional model

The multidimensional nature of data highlights the necessity of representing real-world facts, which represent the object of required analysis to be analyzed to better understand behavior, such as sales and accounting movements in the corporate environment. This involves organizing data into a structure that facilitates intuitive analysis. (24)

Data can be visualized as a cube, and when the number of analysis dimensions exceeds three, these structures are referred to as hypercubes. In this context, a cube represents the aggregation of events that occur over time, described quantitatively by numbers. The analysis dimensions correspond to the axes, as illustrated in Figure 10. For example, a company might wish to summarize financial data by product, by time, and by city to compare actual and budget expenses. Product, time, city, and scenario (actual and budget) are the data's dimensions. (21)

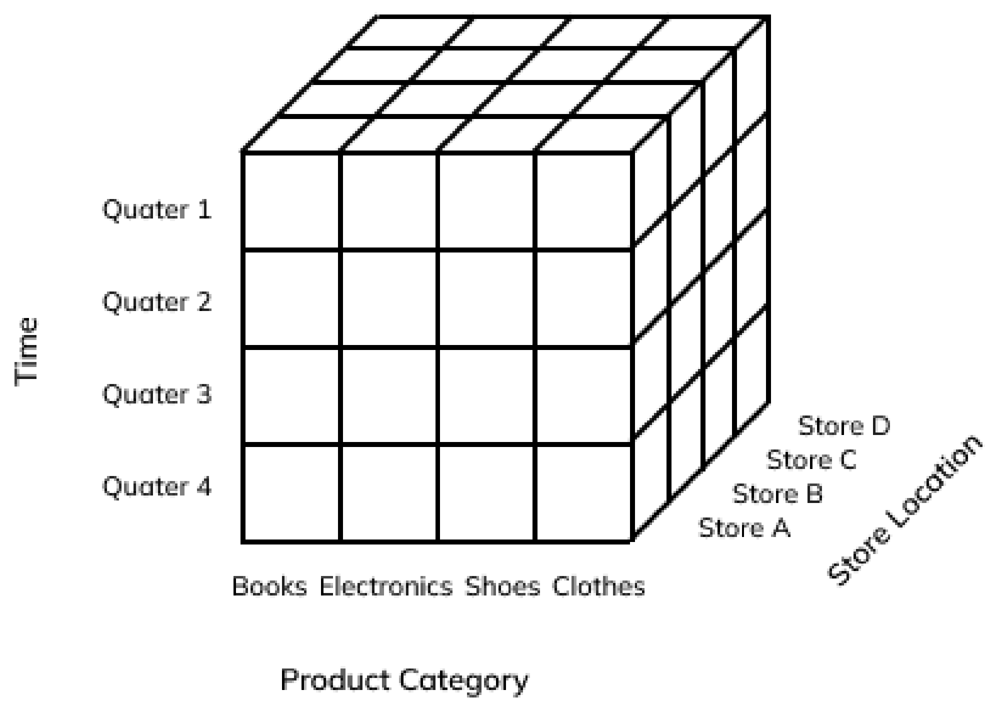

Image 10 – OLAP cube

Once the elements of interest and the information to be used are understood, we proceed with a conceptual modeling technique called the dimensional fact model (DMF) composed by (25)

- Facts are a focus of interest for the decision-making process; typically, they model an event occurring in the enterprise world.
- Dimensions are discrete attributes that determine the minimum granularity adopted to represent facts; typical dimensions for the sale fact are product, store, and date.
- Measure: re continuously valued (typically numerical) attributes that describe the fact from different points of view; for instance, each sale is measured by its revenue.
- Hierarchies are made up of discrete dimension attributes linked by one-to-one relationships and determine how facts may be aggregated and selected significantly for the decision-making process.

3.2.3.1.1 Physical Design

One of the key requirements for a data warehouse system is to ensure efficient performance. To achieve this, additional physical structures known as materialized views are often implemented. These are precomputed summaries of fact tables stored in separate tables designed to optimize frequently executed queries. Instead of querying the original dataset, operations are performed on these pre-aggregated portions, significantly improving response times.

Materialized views are represented within a multidimensional lattice, where each node corresponds to a potential aggregation level. The topmost node reflects the finest granularity of the fact table, while subsequent nodes represent progressively summarized data. As one navigates deeper into the lattice, approaching leaf nodes, the execution times for queries decrease due to the reduced complexity of the precomputed data. These views are generated through SQL operations that traverse dimensional hierarchies, providing an essential mechanism for balancing query performance and storage efficiency in data warehouses. (21)

3.2.3.1.2 Logical Design

After having obtained the conceptual model, the goal is to have a logical relational scheme that is based on the principles of acceptance of data redundancy and denormalization of the tables, which means that the normalization of the tables is renounced. (21)

There are two main relational schemes (21) (26)

- Star Schema: according to this schema, modeling experts must classify model tables as dimensions or facts. The first one, the table of dimensions, describes business entities, which are modeled elements, these entities can be products, people, places, and concepts, including time itself.
  The main characteristic of a dimensional table is the presence of one (or more) key columns, which serves as a unique identifier for other columns and supports data filtering and grouping.
  Instead, Fact tables record specific observations or events, such as sales orders, stock balances, or exchange rates. These tables are structured with dimension key columns, formed by combining the foreign keys of related dimensions and numeric measure columns that hold quantifiable data. The dimensionality of a fact table is defined by its key columns, while its granularity depends on the level of detail in the dimension key values.
  While dimension tables typically have fewer rows, fact tables can expand significantly, accumulating large volumes of data over time due to continuous event recording.

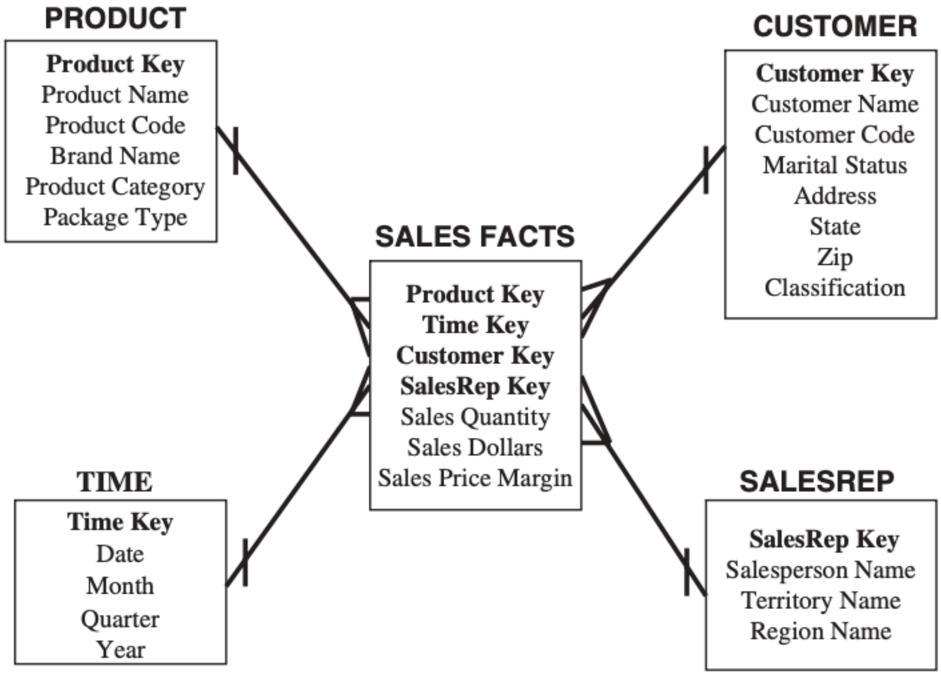

Image 11 – Example of a star schema

- Snowflake Schema: In this schema, the attributes with low cardinality in each original dimension table are removed to form separate tables. These new tables are linked back to the original dimension table through artificial keys.
  "Snowflaking" is a method of normalizing data to eliminate duplicate entities to archive the dimension tables in a STAR schema.
  The original STAR schema for sales, as shown in Figure 11, contains only five tables, whereas the normalized version now extends to 11 tables.
  Normalized structures in databases offer benefits such as reduced storage requirements and easier updates and maintenance due to their organized nature. However, they come with challenges. The schema can be complex and less intuitive, often discouraging end-users. Additionally, browsing through the data becomes more cumbersome, and query performance may decline because of the need for multiple joins to retrieve information.

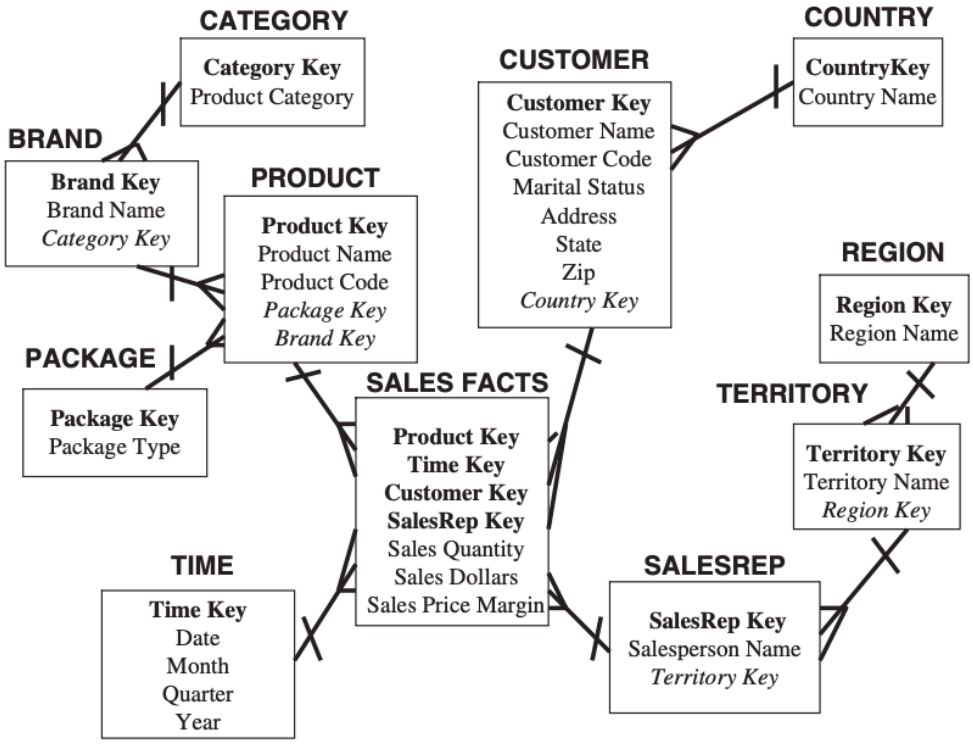

Image 12- Example of a snowflake schema

3.3 Data Analysis

3.3.1 OLAP

For analyzing data stored in a data warehouse, the primary technique used is called OLAP (Online Analytical Processing). This information delivery system is widely utilized because it presents multidimensional views of the data quickly and can also perform complex calculations.

The term OLAP was introduced for the first time in a paper entitled “Providing On-Line Analytical Processing to User Analysts” by Dr. E. F. Codd, the acknowledged father of the relational database model. The paper, published in 1993, defined 12 rules or guidelines for an OLAP system. Later, in 1995, six additional rules were included.
The OLAP council (www.olapcouncil.org), which provides membership, sponsors research, and promotes the use of OLAP, gives a new definition of OLAP which contains all the key ingredients: “On-line Analytical Processing (OLAP) is a category of software technology that enables analysts, managers and executives to gain insight into data through fast, consistent, interactive access in a wide variety of possible views of

information that has been transformed from raw data to reflect the real dimensionality of the enterprise as understood by the user. “
The primary complex calculations that an OLAP server can perform are (21) (27)

- Roll–up: allows the reduction of data details through the elimination of one of the present dimensions or by increasing the level in a hierarchy. For example, you move from a daily to a monthly analysis.

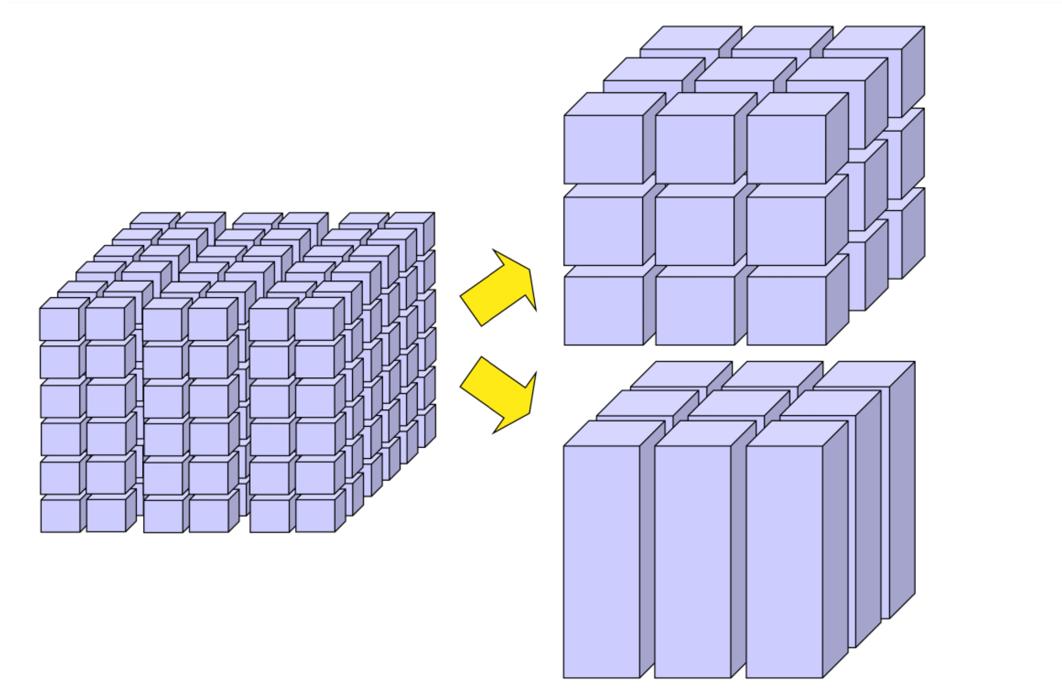

Image 13 – Roll-up operation: cube up with decreasing dimensionality, while cube down retains full dimensionality.

- Drill-down: is the opposite of roll-up, increased data detail through the increase in the level of detail of one of the dimensions present, with the reduction of the level in a hierarchy or by adding a new dimension. For example, you move from a monthly to a daily / product analysis.

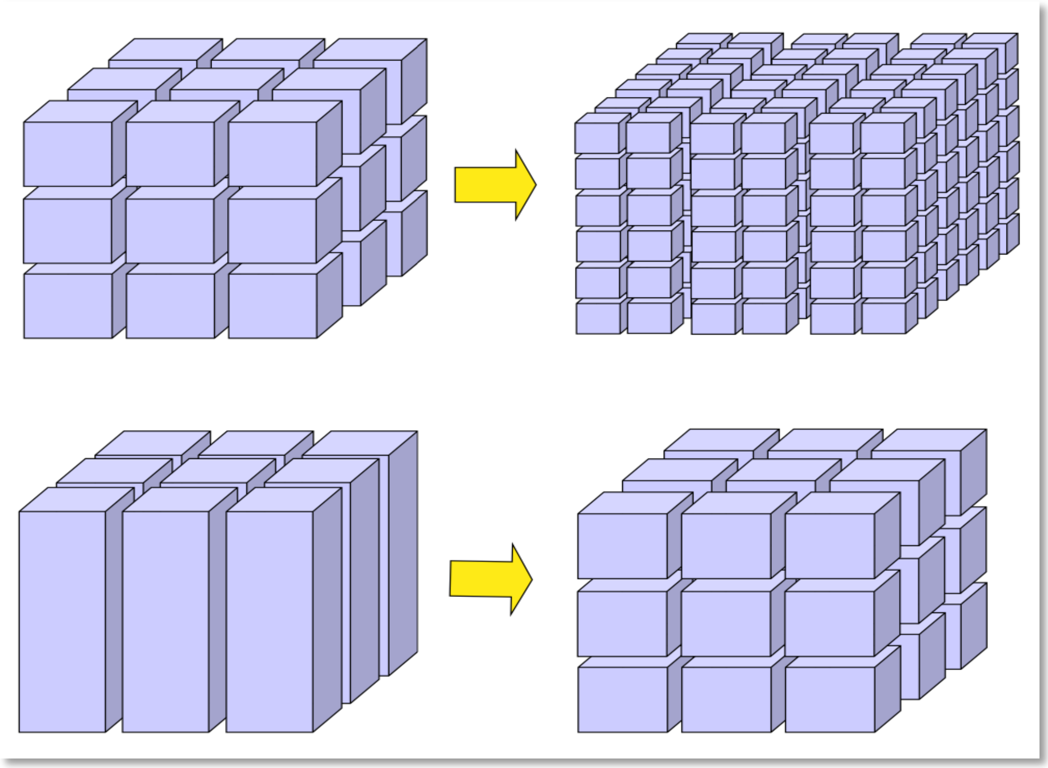

Image 14– Drill down operation.

- Slice and Dice: is the process of reducing the volume of data for analysis by selecting a specific subset using predicates.

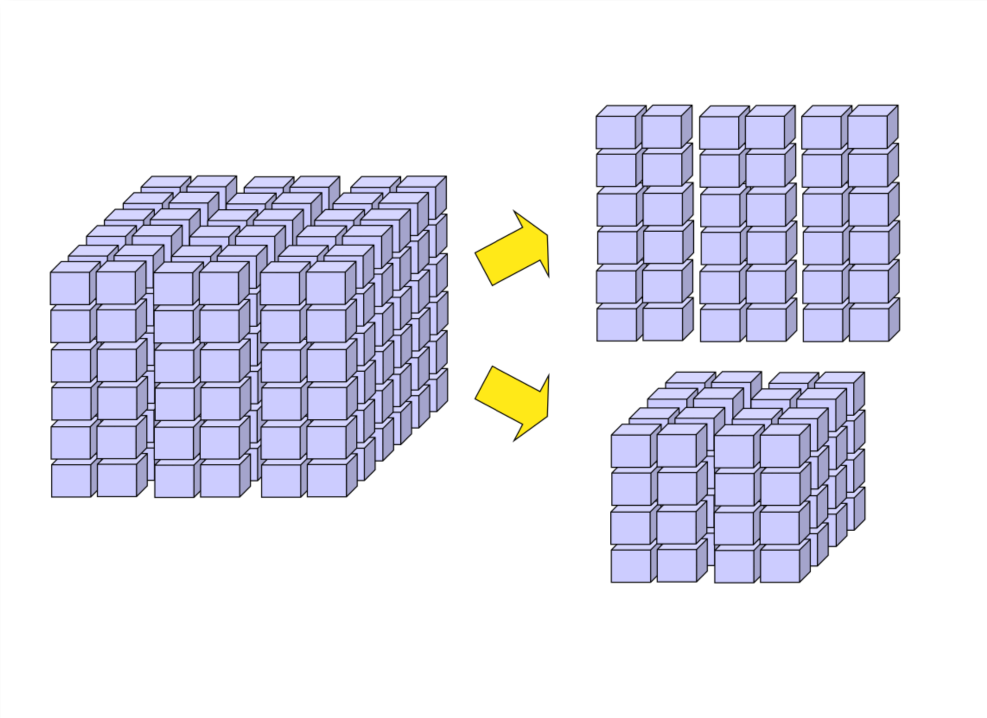

Image 15– Slice and Dice operation.

- Rotation or Pivoting: The reorganization of the orientation of the multidimensional structure without changing the level of detail allows a clearer display of the same information. Thanks to this operation, users can view the data from many angles, understand the numbers better, and arrive at meaningful conclusions.

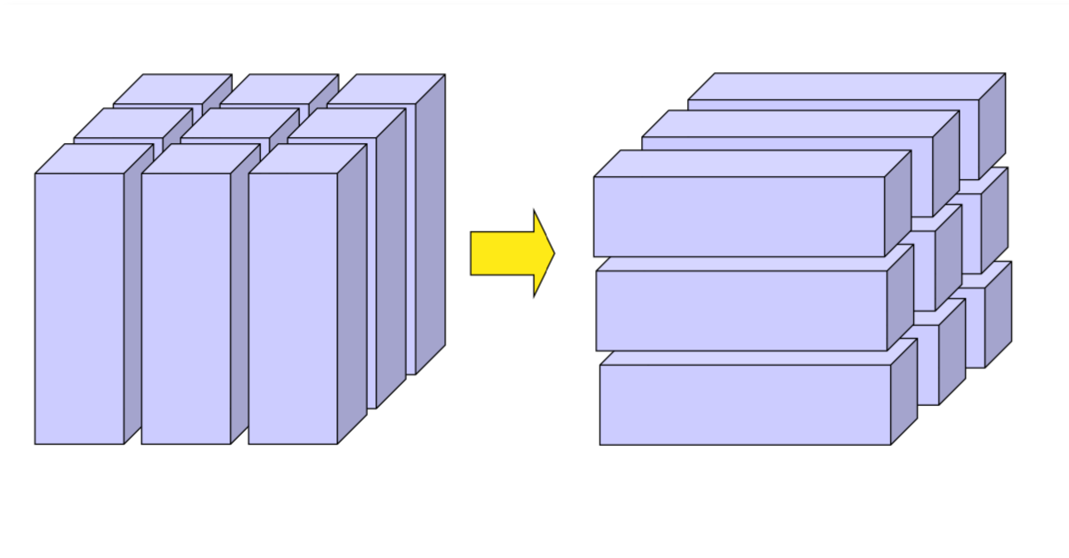

Image 16– Rotation or Pivoting operation.

3.3.1.1 OLAP models

There are different typologies of OLAP servers; the processing is still online analytical processing; basically, the storage methodology is different. (27)

- ROLAP (Relational OLAP): Refers to relational online analytical processing. In this case, the OLAP system is built on top of the existing relational database DBMS of the data warehouse.
  In this model, particularly used for a very large volume, data is stored in a two-dimensional format using rows and columns, like a relational data model.
  To hide the storage structure from the user and present data multidimensionally, a semantic layer of metadata is created. The metadata layer supports the mapping of dimensions to the relational tables.
  When the users issue complex queries based on this multidimensional view, the queries are transformed into complex SQL directed to the relational database. Unlike the MOLAP model, static multidimensional structures are not created and stored.
- MOLAP (Multidimensional OLAP): data for analysis is stored in specialized multidimensional databases. The OLAP engine resides on a special server that is capable of processing large multidimensional arrays from the storage structures, the hypercubes; these cubes require more storage space than ROLAP formats due to sparsity, or the percentage count of cube cells that contain null values but are faster for complex analysis.
  The data structure is fixed so that the logic to process multidimensional analysis can be based on well-defined methods of establishing data storage coordinates. Usually, multidimensional databases (MDDBs) are vendors' proprietary systems and are preferred for moderate data volumes with highly complex analysis.
- HOLAP (Hybrid OLAP): HOLAP. Refers to hybrid online analytical processing. This model attempts to combine the strengths and features of ROLAP and MOLAP. Therefore, it allows data storage both within cubes and within two-dimensional tables, thus obtaining a fair trade-off between performance and space management.

- DOLAP (Desktop OLAP): Refers to desktop online analytical processing. DOLAP is meant to provide portability to users of online analytical processing. In the DOLAP methodology, multidimensional datasets are created and transferred to the desktop machine, requiring only the DOLAP software to exist on that machine. DOLAP is a variation of ROLAP.

3.3.2 Data Mining

Data mining is also known as a knowledge discovery process that helps to understand the substance of the data in a special, unsuspected way.
Its objective is to identify useful patterns by learning from past associations and results and to predict customer behavior.
Joseph P. Bigus, in his book Data Mining with Neural Networks (1996, p. 9), described Data Mining as “the efficient discovery of valuable, non-obvious information from a large collection of data.” (27)
There are a lot of different techniques used in this process, and they can be divided into two different categories: supervised learning requires prior knowledge about the data for implementation, while unsupervised learning is the exact opposite. (21)

- Cluster Detection: Clustering is an unsupervised technique that does not rely on pre-classified data and makes no distinction between independent and dependent variables. It identifies and groups objects based on their common characteristics. This approach enables more targeted and appropriate actions for each item within the cluster.

- Decision trees: This technique applies to classification and prediction. The major attraction of decision trees is their simplicity. By following the tree, it is possible to decipher the rules represented by a decision tree and understand why a record is classified in a certain way. These rules can be used to retrieve records falling into a certain category. This technique is used when the reasons for the prediction are important.
  A decision tree represents a series of questions, and each question determines what follow-up question is best to be asked next. Good questions produce a

short series. Trees are drawn with the root at the top and the leaves at the bottom, an unnatural convention. (27)

- Memory-based reasoning uses known instances of a model to predict unknown instances. This data mining technique maintains a dataset of known records. The algorithm learns the characteristics of the records in this training dataset. When a new record arrives for evaluation, the algorithm finds neighbors like the new record and then uses the characteristics of the neighbors for prediction and classification.

  When a new record arrives at the data mining tool, first, the tool calculates the "distance" between this record and the records in the training dataset. The distance function of the data mining tool does the calculation. Next, the algorithm uses a combination function to combine the results of the various distance functions to obtain the final answer. The distance and combination functions are key components of the memory-based reasoning technique.

- Link analysis: This algorithm is extremely useful for finding patterns from relationships and for discovering links among variables by their values.

- Neutral network: mimics the human brain by learning from a training dataset and applying the learning to generalize patterns for classification and prediction. These algorithms are effective when the data is shapeless and lacks any apparent pattern. This network consists of nodes, the basic units, connected by links.

Expanding the range of analytical tools enhances the ability to address a wider variety of scenarios and challenges. It provides diverse perspectives for problem-solving, enabling a more comprehensive approach to understanding and decision-making.

3.3.3 Data Visualization

When a user queries a data warehouse, he expects to see results only in the form of output lists or spreadsheets. For this reason, results need to be displayed in the form of graphics and charts.

Visualization of data in the result sets boosts the process of analysis for the user, especially when the user is looking for trends over time. Data visualization helps the user interpret query results quickly and easily by displaying information in several types of visual forms: text, numerical arrays, spreadsheets, charts, graphs, and so on. A lot of progress has been made in data visualization, including information through dashboards and scorecards. (27)

The primary graphic representations utilized are: (28)

- Bar chart: is a graph used to represent characters, often qualitative. The diagram makes use, but not necessarily, of an orthogonal Cartesian reference system, and it is useful when the number of items you want to analyze is not large.

- Pie chart: for qualitative characters and shows the proportions of the parts to the whole. It is based on the correspondence between frequencies or intensities on one part and surfaces of circles or circular sectors on the other. It is suitable for a limited number of categories, as too many items would lead to difficult visualization.

- Histograms: They represent statistical data using rectangular surfaces. They also make use of the system of cartesian axes and lend themselves very well to representations of continuous quantitative characters with modes grouped into classes of values that may be of equal magnitude or less.

4 Impact of business intelligence and big data on business processes and decisions

4.1 Corporate Performance Management CPM and Management Control System (MCS)

Corporate Performance Management (CPM), also called Enterprise performance management (EPM) or Business Performance Management (BPM), is the integration of control and improvement methods embedded with analytics.

Its methods include the strategy map, balanced scorecards, costing (including activity-based cost management), budgeting, forecasting, and resource capacity requirements planning. These methods fuel other core solutions such as customer relationship management (CRM), supply chain management (SCM), risk management, and human capital management systems. (29)

Gartner Research, a leading company in information technology research and analysis, provides another definition:

"Corporate performance management (CPM) is an umbrella term that describes the methodologies, metrics, processes, and systems used to monitor and manage the business performance of an enterprise. Applications that enable CPM to translate strategically focused information to operational plans and send aggregated results. These applications are also integrated into many planning and control elements cycle, or they address BAM or customer relationship optimization needs.

CPM must be supported by a suite of analytical applications that provide the functionality to support these processes, methodologies, and metrics." (30)

Being a CEO has become increasingly demanding in today's fast-paced, competitive environment. Customers continue to commoditize products and services, intensifying price pressures. Meanwhile, business challenges such as frequent mergers, layoffs, and market volatility create a complex landscape for senior leaders. Boards of directors, now more active than ever, have heightened their expectations, holding executives accountable for delivering financial results and meeting shareholder demands. Consequently, involuntary turnover rates among executives have risen significantly.

The main culprit behind many CEO departures lies in the inability to execute strategy effectively.

EPM offers effective tools like the balanced scorecard and strategy maps that enhance a company's strategy. Its strength lies in enabling informed choices through the continuous adjustment and effective execution of strategies. By helping managers to detect changes early, EPM allows them to respond quickly and effectively to uncertainties. In summary, EPM equips an organization with the ability to anticipate, react, and respond swiftly to evolving situations.

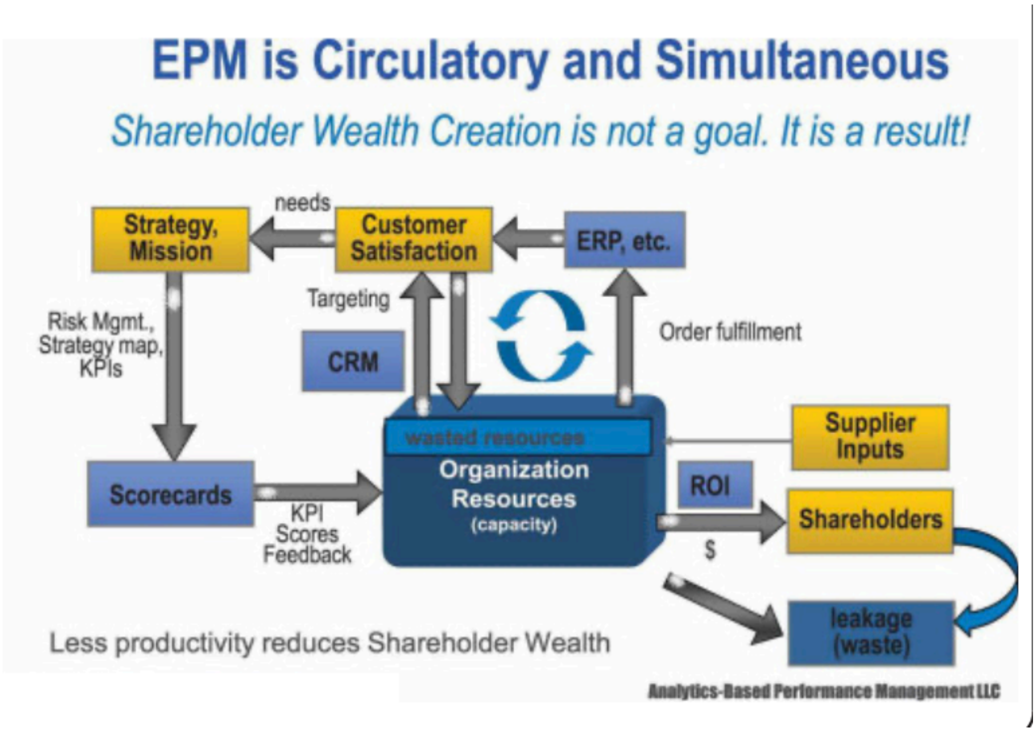

Image 17–Performance Management is circulatory and simultaneous.

Management control was defined by Anthony (1965) as "the process by which managers ensure that resources are obtained and used effectively and efficiently in the accomplishment of the organization's objectives."

Management control system focuses on monitoring and control, ensuring the organization's operations run as planned and within budget. (31)

To ensure optimal organizational performance, it is critical to adopt a systematic approach that integrates insights from process design, employee capabilities, and performance management systems, In this scenario, the impact of the EPM on the MCS is given thanks to (32):

- Optimizing Process Behavior Organizations should analyze data from inputs, processes, and outputs across multiple workflows to identify the behaviors that lead to peak performance. This helps prevent sub-optimization (where one part of the process is improved at the expense of others). Leveraging real-time feedback, behavior adjustments can be automated, ensuring processes remain aligned with performance goals even as circumstances change.
- Aligning Employee Capabilities with Organizational Needs: Understanding which employee characteristics, skills, and knowledge contribute to high performance is essential. Regular assessments can identify gaps in critical skills or redundancies. In dynamic environments, organizations must also anticipate the skills and knowledge needed in response to external changes, such as technological advancements or market shifts.
- Setting and Refining Output Targets: Effective performance management involves setting output targets that drive optimal results. Targets should be regularly evaluated and adjusted to address deviations or changing external conditions. Analyzing the relationships between performance indicators, outputs, and rewards enables the design of an incentive system that motivates employees while aligning with organizational goals.
- Sharing Performance Data Transparently: Making performance information accessible to employees across all levels promotes accountability and collaboration. When individuals understand how their contributions affect broader organizational goals, they are better equipped to adjust their actions to meet expectations. This transparency also fosters peer evaluation, encouraging a collective effort toward achieving targets.
- Providing Management with a Holistic Perspective: Managers benefit from an aggregated view of performance data, allowing them to identify trends, challenges, and opportunities. By combining local insights with an overarching organizational perspective, leadership can make informed strategic decisions to sustain long-term success.

This approach emphasizes continuous improvement, adaptability, and alignment between individual, team, and organizational goals. By integrating these elements,

organizations can cultivate a responsive, high-performing environment that meets evolving demands.
For a company, the use of these two management models is crucial to be competitive in today's market.

4.1.1 Reporting and Key performance indicator

To support decision-making and provide relevant information to entrepreneurs and managers, an organization needs to have an effective corporate reporting system. Reporting serves as a management control tool designed to provide an overview of the company's performance and offer useful insights into the organization's health. (33)
Entrepreneurs and managers require continuous monitoring of operations, not just annual evaluations through financial statements.
The primary goal of management control is to provide interim analyses, specifically to evaluate (34) :

- Past trends in performance.
- Competitors and market positioning.
- The budget is a tailored reference model for planning and comparison.

This process involves comparative analysis, comparing the current financial statements with those of the previous year, and variance analysis, which periodically (often quarterly) compares the current situation with budgetary targets. Such practices enable the assessment of actual results against budgeted projections, allowing adjustments to be made for improved outcomes in future periods. (32)

Reporting systems vary in complexity and capability, but it is widely accepted that organizations cannot operate effectively without them. Reporting activities are crucial for collecting and processing data to support decision-making.
The information generated must meet certain key characteristics, including: (35)

- Timeliness enables action before issues become irreversible.
- Relevance to capture variables useful to the report’s audience.

- Reliability depends heavily on the accuracy of data sources and analysis systems.

Additional important factors include the clarity, comparability, and readability of reports, as well as tailoring the level of detail to the organizational hierarchy, with higher levels requiring less detail. (35)

Reports also heavily rely on Key Performance Indicators (KPIs), which provide a simple, quick assessment of whether the company, teams, or departments are working effectively and meeting objectives. KPIs are central to understanding performance due to their ability to communicate insights clearly and concisely, making them invaluable for summarizing results. (36)
These indicators can be defined in various ways depending on the business model, within management control, they can also be used as a planning tool that helps plan future activities with a view to improvement where there are deviations between the expected results and those obtained, management can take the necessary actions to correct the gap.

4.2 Big Data Management in MCS

Big data refers to large and complex data sets. In 1958, IBM defined big data as "the ability to understand the interrelationships of presented facts in such a way as to guide action toward a desired goal."(37)

Big data has the potential to significantly benefit the global economy by enhancing productivity, increasing competitiveness, and generating economic surplus for consumers. To fully harness its potential, it is crucial to utilize appropriate analysis techniques that ensure computational speed, scalability, and programmability, particularly for applications that involve streaming data, graph data, machine learning (ML), and artificial intelligence (AI). (37)

An essential concept related to big data is the three V's: volume, speed, and variety.

- Volume: The quantity of data is significant. In the context of big data, organizations must process large volumes of unstructured data, often characterized by low density and uncertain value. For some organizations, this may involve managing tens of terabytes of data, while others may deal with hundreds of petabytes. (37)
- Speed: Velocity refers to the rate at which data is received and processed. Typically, the highest volume of data flows directly into memory rather than being saved to disk. Some functions necessitate real-time evaluations and actions. (37)
- Variety: Variety refers to the many types of data available. Traditional data types were structured and perfectly suited to a relational database. With the advent of big data, data comes as new types of unstructured data. Unstructured and semi-structured data types, such as text, audio, and video, require additional preprocessing to derive meaning and support metadata. (37)

Appropriate technologies and infrastructures are essential to fully utilize the hidden potential of data. These elements facilitate the entire process of extracting knowledge to support end users. It's crucial to find the right balance between hardware technologies, which enable the transmission, storage, and processing of information, and software infrastructure, which includes all the algorithms required for analysis.

The use of Big Data has transformed the way Bios Management S.r.l. analyzes and leverages information to support business decisions. Specifically:

- Predictive analytics has made it possible to identify market trends, leading to more effective strategic planning.
- Advanced data management has helped reduce budgeting forecast errors by 20%, improving financial accuracy.
- The integration of data mining models has uncovered correlations between financial and operational data, enabling more informed decision-making.

4.3 BI and Six Sigma to improve quality

Integrating Business Intelligence into decision-making isn't just about crunching numbers it's about making smarter, more informed choices that drive better outcomes. As Visinescu et al. (2015) highlight, BI helps organizations turn vast amounts of raw data into meaningful insights, allowing for more accurate and timely decisions. But for BI to truly make an impact, it all comes down to the quality of the data and how effectively people use it. (38)

This is where Six Sigma comes into play. Known for its structured DMAIC approach (Define, Measure, Analyze, Improve, Control), Six Sigma relies on data-driven problem-solving to reduce variability and boost overall performance. When combined with BI, it takes quality improvement to the next level. Organizations can leverage advanced analytics, process monitoring tools, and root cause identification techniques to highlight inefficiencies and make targeted improvements. (38)

Even more, by using data mining and predictive analytics, BI helps anticipate potential issues before they arise, optimizing decision-making strategies and ensuring continuous performance control. The combination of BI and Six Sigma isn't just about improving processes it's about fostering a culture of continuous improvement, reducing waste, and making operations more efficient and effective at every level. (38)

Statistically, Six Sigma refers to a process in which the range between the mean of a process quality measurement and the nearest specification limit is at least six times the standard deviation of the process. (39)

Six Sigma stands out from other quality improvement programs due to its structured, top-down approach and rigorous methodology, which emphasize thorough analysis, data-driven decision-making, and continuous process control. Developed by Motorola in the 1980s, Six Sigma has since been successfully adopted by major corporations such as GE, Honeywell, Sony, Caterpillar, and Johnson Controls, delivering substantial benefits. (39)

At its core, implementing Six Sigma requires a long-term commitment and strong backing from top management. More than just a set of tools, it fosters a cultural shift within an organization, encouraging fact-based decision-making at every level. Recognizing its transformative potential, researchers have studied Motorola’s experience with Six Sigma, highlighting it as a valuable framework for any company striving to enhance quality. (39)

5 The Platform BOARD

5.1 Structure and Functionality

BOARD is an all-in-one platform for corporate decision-making that has enabled employees of more than 3000 companies around the world to have an innovative impact on their business by integrating applications of Business Intelligence (BI), Corporate Performance Management (CPM), and Predictive Analytics within a single, intuitive, and flexible environment. (40)

BOARD is designed to meet the analytical, planning, and simulation needs of modern organizations, among the most important companies there are Toyota Motor Europe, Coca-Cola European Partners, and Siemens. It distinguishes itself by centralizing data and decision-making processes, which reduces the complexity associated with using fragmented tools. As part of the category of products that put technology at the service of business management needs, BOARD functions as a marketing intelligence Toolkit. This software is highly versatile and exceptionally user-friendly, resulting in low training costs for users. (40)

The all-in-one solution integrates: (40)

- Business intelligence: Scorecarding, Dashboard, Reporting, Analysis
- Performance Management: Budgeting, Planning, Forecasting, Profitability, Analysis, Strategy Management, Financial Consolidation.
- Predictive Analytics: Machine Learning Forecasting, Simulation, Clustering, Statistical Functions.

Image 18- Functionalities of Board

“Microsoft data centers control and manage customer data, being able to leverage over two decades of experience keeping data safe and complying with privacy requirements and compliance.” This is what Nelson Petracek, CTO of Board International, says.

The intelligent planning solutions offered by the Board allow you to carry out activities support in various sectors:

In the finance sector, which focuses on financial analysis, budgeting, planning and forecasting, group consolidation and reporting, and, ultimately, strategic and capital planning, it is possible to: (40)

- Accelerate planning cycles, creating a fast and fluid planning process that ensures total alignment between all the subjects involved. Automating the process allows the Department of Finance to focus more on strategy analysis and implementation rather than on squaring the data. Create simple different what-if scenarios and monitor the differences.
- Integrates processes connecting data between the various systems brings together all departments in one platform and ensures that all refer to the same version of the information.
- Collaborate flexibly, allowing all planners to work together simultaneously thanks to shared dashboards and a built-in chat interface.
- Switch to xP&A expanding planning beyond the financial function and achieve an optimal extended planning and analytics (xP&A) approach.
- Focus on insights, reducing the time spent collecting data and past performance, and make processes more agile to promote long-term strategies.

In the Supply chain, especially for sales, operations, and demand planning, you can monitor the whole process through (40)

- More flexible planning accelerates planning cycles and improves efficiency by seamlessly adapting to changes in supply and demand with Machine learning algorithms.
- A Rough-Cut Capacity Planning (RCCP) type allows you to identify the key resources for production and, therefore, align operational capacity with forecasted demand.
- Optimized profitability, increasing profitability and reducing costs with effective planning and inventory management.

In the Human Resources (HR) area, human resources can be effectively managed through: (40)

- Workforce planning enables alignment between corporate goals and the workforce responsible for implementing them.
- Maximizing workforce efficiency by using key drivers to extract detailed information that supports personnel management, such as employee retention and turnover data.
- Aligning corporate objectives with individual goals, identifying talents, and monitoring employee performance. This facilitates more informed decisions regarding incentives and compensation, ensuring the optimal allocation of financial resources.

In the sales area, performance management can be achieved through (40)

- Effective sales planning, including customer segmentation based on preferences and purchasing needs. This improves sales budgeting processes and sales quota planning for sales representatives and geographic areas.
- Proper sales team management by planning appropriate incentives and compensation based on the monitoring of sales team performance.

Thanks to its scalable architecture and cloud support, BOARD is an ideal solution for both large enterprises and mid-sized organizations seeking to enhance competitiveness through data-driven and informed decision-making processes.

5.2 Components

Board was developed in 1994 by Board International SA. Over the years, several versions have been released, and the latest is version 14, which includes many tools divided into five macro areas: (40)

- Data Model
- Capsules
- Presentations
- Cognitive Space
- System Administration

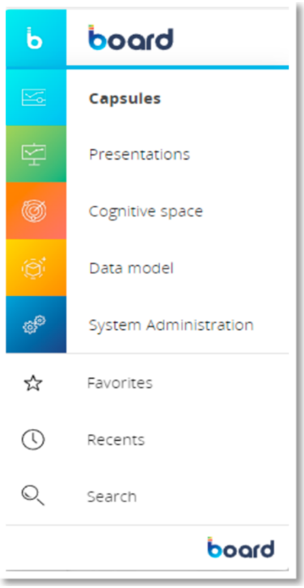

Image 19- Board Menù

5.2.1 Data Model

Board's Data Model technology is designed to maximize efficiency in handling vast amounts of data, ensuring high performance in data reading, manipulation, and visualization. The implementation represents the final phase of a comprehensive project process, which begins with collecting and analyzing the requirements of end users and culminates in defining the specifications for the multidimensional data model. (41)

Board's Data models are multidimensional and are, therefore, optimal for online analytical processing (OLAP). The concept behind data modeling in Board revolves around the creation of data cubes, where each cell represents a value obtained from the intersection of n dimensions of the cube, corresponding to the aspects to be analyzed. For instance, a cube analyzing revenue might have dimensions such as customers and geographic area. These analytical dimensions are referred to as entities (for example, month, client, and product as shown in Figure 20) and can be interconnected through relationships, establishing a specific hierarchy (41).

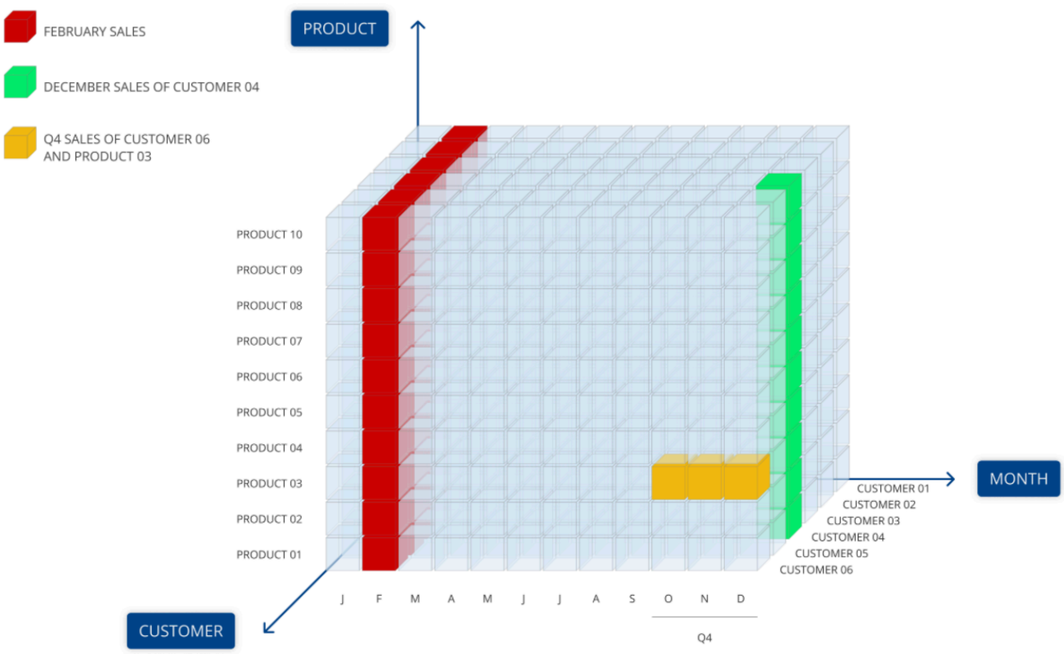

Image 20- Example of a cube structured by Entity

Board enables data writing not only through cube structures but also directly to a variety of relational data sources, including:

- Relational databases and Data Warehouses
- Enterprise applications such as SAP ERP
- Multidimensional sources, including SAP BW
- Web Services via API calls

- Flat files, such as Excel, CSV, and TXT
- Cloud-based data sources

This functionality is made possible through OLE DB and Open Database Connectivity (ODBC) connections, ensuring seamless integration with diverse data environments.

The main components of Board's data model are illustrated in Figure 21:

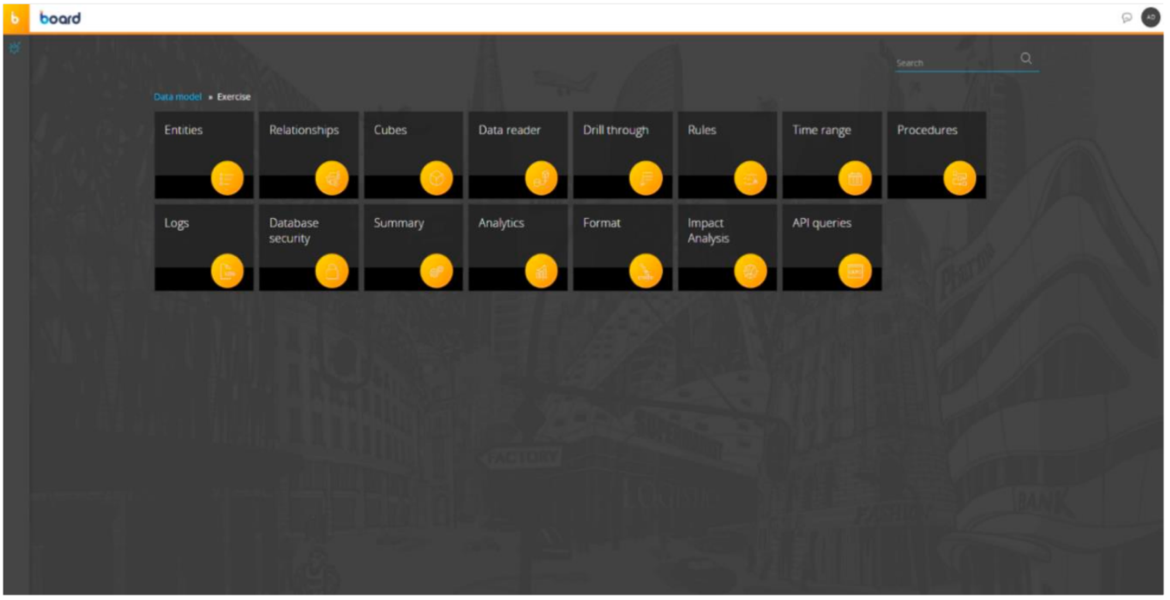

Image 21- Board Data Model

The supporting elements of Board's data model, such as logs, format configuration, and impact analysis, enhance the data management framework's flexibility, usability, and integrity. Logs provide detailed records of actions performed within the system, including data updates and user activities, ensuring robust tracking and troubleshooting capabilities. The format configuration feature allows for the creation, editing, and management of style templates, enabling the customization of formatting elements such as backgrounds, borders, and fonts for individual members. This ensures a consistent and professional presentation of data.

Impact analysis, on the other hand, provides an in-depth examination of the connections between all elements within the data model structure. This capability is particularly useful for understanding the potential repercussions of changes to the data model, as it allows users to assess how modifications might affect Board applications reliant on the altered structure. Together, these components enhance the flexibility, usability, and integrity of Board's data management framework. (41)

To correctly implement the model, it is essential to follow the phases in an orderly manner: defining the time range, creating the entities, establishing the relationships, creating the cubes, and loading the data using data readers. This sequential approach is necessary because each step depends on the previous one. For instance, creating and analyzing cubes requires the entities and their possible relationships, and loading data depends on having cubes on which the data can be read.

5.2.1.1 Time Range

The first step to be performed within Board to properly build a data model is the definition of the time range, this initial configuration usually reflects your existing data lifespan and extends for a few years in the future for planning purposes. (41)

The minimum length of a time range is one year; in that case, the start year and the end year are the same. The maximum extent of a time range is 110 years, with the earliest being 1990 and the latest 2100. (41)

In Board, four native time entities -Day, Week, Quarter, and Fiscal Year- are predefined, and the relationships between them are automatically set.
Users also can create up to four custom time entities (for example, Season). The key difference with custom time entities is that their relationships with existing time entities must be manually defined.
It is possible to modify the time range setting; you can extend the end year and add or remove new time entities without needing to perform additional activities on the data. However, if you want to change the start year or reduce the end-year range, the data in all cubes will be deleted. In this case, you will need to extract the data beforehand and reload it after making the changes. (41)

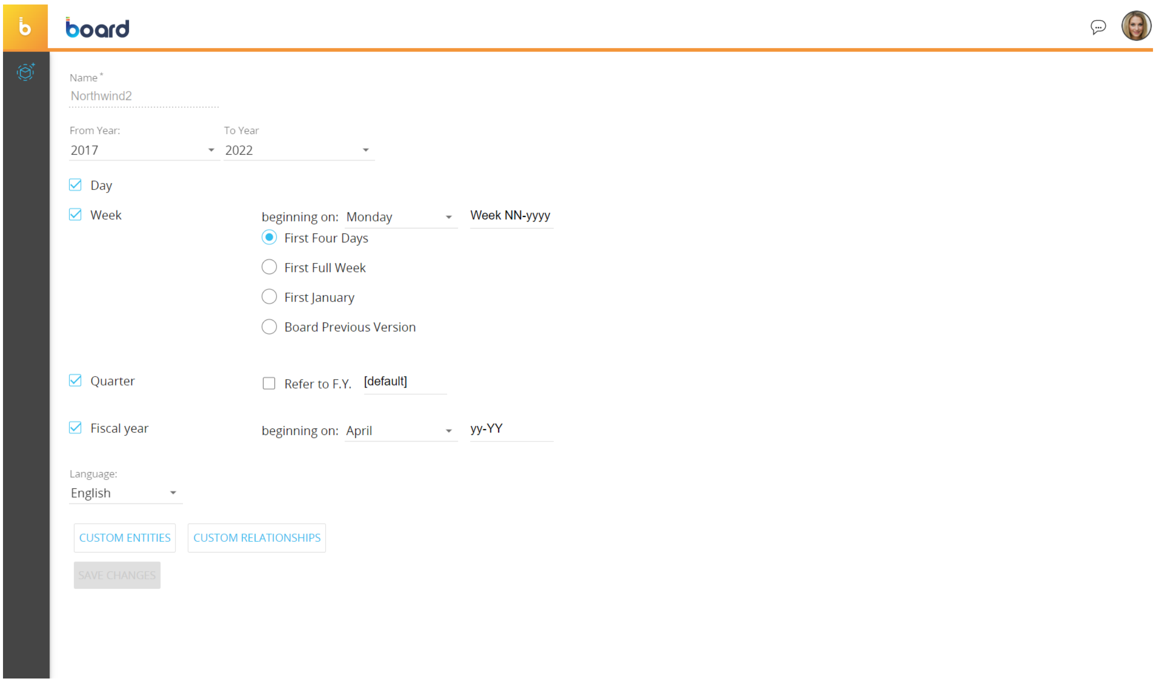

Image 22- Time Range

5.2.1.2 Entity

An Entity generally is a set of homogeneous items by which data can be viewed and summarized. A single occurrence of an Entity is called an "Entity member," "item," or simply "member". Each member of an Entity is defined by two values: the code and the description. The code is a unique value that identifies every single member. The description is a text string that describes the Entity member in more detail and can be any number of characters long. (40)

Entities in Board are typically used as dimensions of Cubes, but they can also be added as Data Blocks or in the Axes of a Layout.

An important property is the max item number, the maximum number of members that the Entity can hold. It is important to set a value that would suit the potential rate of growth of new members over the life of the application. Still, this value shouldn't be unrealistically high, as it is used for allocating memory in the application and for optimizing the physical data structure of Entities and Cubes. (40)

When two or more Entities have a many-to-one relation, then a Relationship (or hierarchy) can be defined. Otherwise, the entity can be called “Stand Alone”.

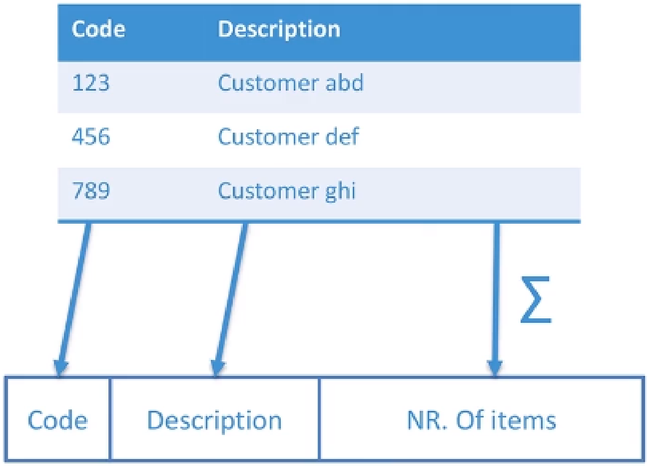

Image 23- Example of entity members

5.2.1.3 Relationships

Once the entities of the model are defined, it is important to establish relationships between them where necessary.

In a Board data model, relationships are always hierarchical. A relationship defines a many-to-one connection between two entities, where one is considered the parent entity and the other the child entity. This is why these relationships are often referred to as hierarchies or trees in typical Board scenarios.

Hierarchies should reflect the true structure of the business model or organization being represented. A relationship between two entities should only be established if there is a clear organizational rule or requirement that justifies it, ensuring the relationship mirrors real-world connections within the data model.
The following tree diagram shows a typical Relationship where the Customer Entity is related to different Entities belonging to separate branches.

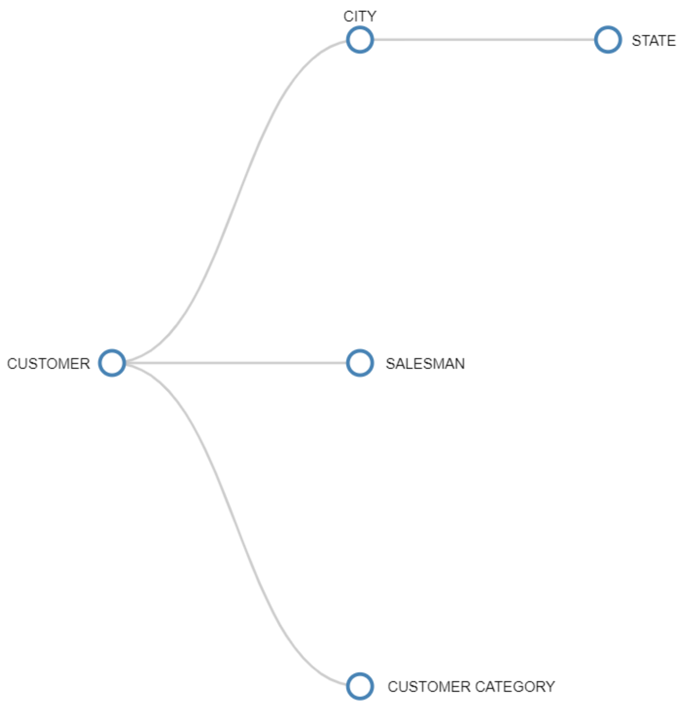

Image 24- Example of Relationship

5.2.1.4 Cubes

Cubes contain data (often numerical but not strictly) that can be analyzed and viewed by their different dimensions and hierarchy levels. (41)

An important concept when discussing cubes is cube density. This measure is defined as the ratio between the number of cells containing data and the total number of cells in the cube.

With Board, you can define cube density by choosing to set an entity as sparse or dense. This choice directly impacts performance and data storage efficiency. Sparse entities minimize storage by only occupying space when data exists, while dense entities allocate space for all possible intersections, ensuring faster calculations but consuming more memory. Only temporal entities must have a dense structure on Board. This ensures that all time periods are accounted for without gaps, supporting continuous and accurate analysis across various time dimensions. (41)

5.2.1.5 Data Readers and Procedures

Data is usually imported into Board via Data Readers. Data Readers also handle the mapping of data to Entities, Relationships, and Cubes.

Imported data can be later manipulated using Data model procedures.

From a technical point of view, Board leverages the following list of data providers to import data from external sources: (41)

- Open Database Connectivity (ODBC) standard and OLE DB to connect with relational databases
- CSV and TXT files

Image 25 – Mapping a Data Reader

To start a data reader in Board, you can initiate the process either through a procedure or directly from the dedicated section within the data model. Board's high flexibility allows you to feed the model directly from source systems like ERP and CRM without the need for intermediate layers such as Data Marts or Data Warehouses. This streamlines the data integration process, enabling real-time updates and minimizing latency.

A Procedure is a customizable sequence of Actions (also called Steps) belonging to various action groups depending on their purpose. Capable of performing a broad range of tasks: for example, it can be used for updating a Board Data model, processing, extracting or printing data, performing calculations, broadcasting reports, and navigating Capsules and Screens. They can also be used for hidden tasks that process data, from simple calculations of values in Cubes to complex allocation procedures required in business models such as budgeting, planning, forecasting, profitability models, and business simulations in general.

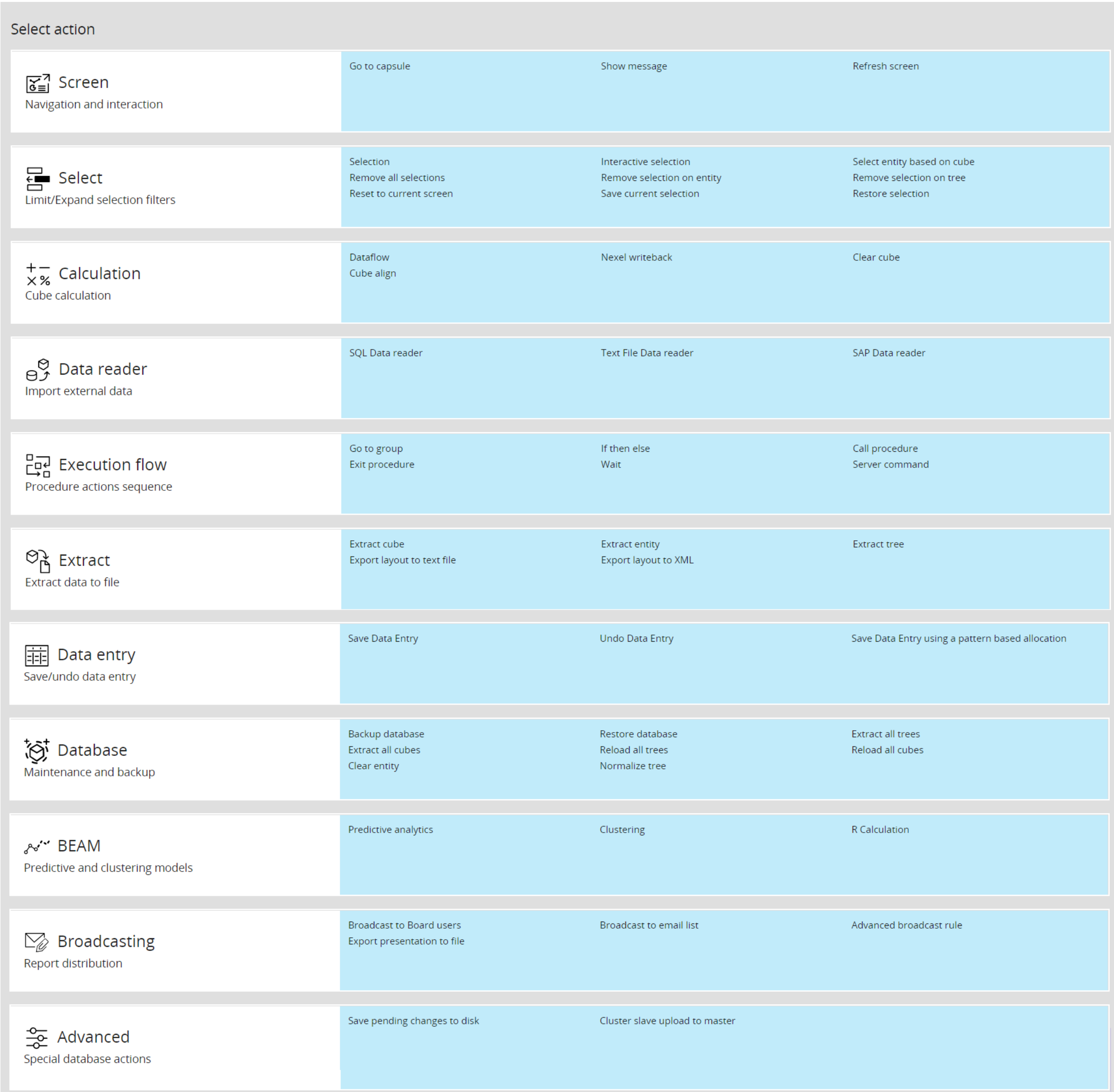

Image 26 – Procedure actions

5.2.2 Capsules

A Capsule is a free and unstructured environment for ad-hoc analysis. Users with the necessary permissions can create their Capsules and manage them in folders. The Capsule Design mode provides tools and Objects with native features for analysis for creating simple reports or sophisticated business models. (41)

A Capsule is a collection of Screens and Procedures. Screens can be considered reports and can contain various Objects such as tables, charts, buttons, text, and other data visualization features. Depending on your License and the Objects settings, you can also perform data entry actions, calculations in real-time, and other data manipulation activities.(41)

5.2.3 Presentation

Board's Presentations are a great step ahead in closing the gap between corporate data governance and individual analysis needs. Board's powerful Presentations environment enables business users to easily create customized versions of enterprise reports to perform ad-hoc analyses based on specific personal needs.

Presentations are initially associated with the user who created them (the owner). Board's in-context collaboration services make it possible to immediately share new insights with a single person or a workgroup: recipients can also be allowed to edit shared Presentations to collaborate on the same reports together. (41)

A Presentation lends itself to a wide range of purposes, just like a Capsule. The main difference is that a Presentation is personal and, unless shared, it is only accessible by the user who created it. (41)

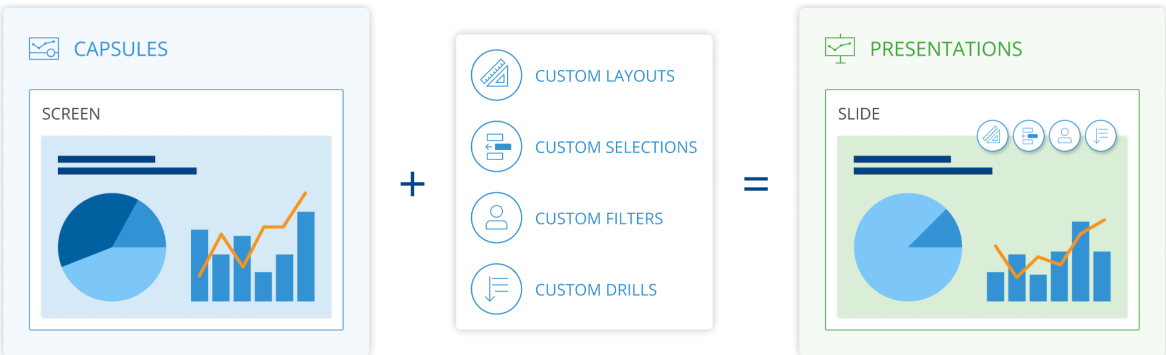

Image 27- From Capuses to Presentation

5.2.4 Cognitive Space

Thanks to the introduction of Natural Language Recognition (NLR) and Natural Language Generation (NLG) technologies, the Board allows an extremely innovative and effective interaction between users and data on the entire Board Platform, delivers a truly web-like search experience, and saves time.

The user can request information, which will be translated into queries. Board will then provide a series of key and highly relevant analyses and reports based on the system's interpretation of the request. (41)

5.2.5 System Administration

The System Administration section of Board is dedicated to administrators of a single Platform. This section is not accessible to all users; it is only for those who have a developer license and an appropriate security profile. (41)

The main areas are:

- User & Security: here, it is possible to define user authorizations regarding folder access, Capsules access and editing, and data model access and editing. (41)
- Monitoring: review user activities, see which tasks are currently running, and configure system logs. (41)
- Administrator: It is possible to manage the Broadcasting feature to send emails to a pre-defined list of recipients, configure data sources, adapt text from one language to another, and customize the visual elements of the user interface. (41)
- Transporter: It is possible to take Data model snapshots to compare them and apply metadata changes from a source Data model to a target Data model. (41)

6 Case study

The implemented application is designed to optimize the use of the vast amount of data generated daily by the company, which operates within a structured and complex organization. Like many modern businesses, it struggled with challenges in managing and analyzing this data, making effective decision-making more difficult. By addressing these issues, the application enhances data accessibility and usability, helping the company make more informed and strategic decisions.

To address these challenges, the implemented application developed by me based on feedback from the company's controllers, aims to optimize the use of this extensive data, specifically in the HR domain, by facilitating both strategic and operational decision-making. The goal is to provide an intuitive and user-friendly environment where all users can easily access various areas of analysis from a centralized main screen.

The key challenges identified were:

- Fragmented data sources: Information was scattered across multiple systems (ERP, CRM, Excel spreadsheets, and legacy databases), making integration difficult.
- Lack of a unified view of business performance: Data was not available in real-time, and reports took a long time to generate.
- Difficulty in tracking key performance indicators (KPIs): Business leaders lacked advanced analytics tools to assess operations on time.
- Decisions driven by intuition rather than data: The absence of sophisticated analytics tools limited the company's ability to leverage forecasting and scenario analysis effectively.

The goal is to provide an intuitive working environment for users, allowing everyone to access the various analysis areas from a main screen. All choices are aimed at correcting the errors mentioned above.

In this section, both functional and non-functional requirements for the creation of the Financial Planning process (also known as the Budget process) will be analyzed. The workflow of the process is divided into four steps:

- Setting
- FTE
- Cost
- Scenario

An important premise, applicable to all steps of the workflow, is that the budgeting process spans the 12 planning months following the closing reference month.
All the data used in the following model is fictitious.

6.1 Bios Management S.r.l

Bios Management S.r.l is a consulting firm that has been guiding businesses across various industries on their path to innovation for over 20 years. With a focus on strategic, managerial, and digital consulting, the company helps organizations enhance their operations by implementing advanced digital solutions, driving efficiency, and implementing growth.

Bios specializes in implementing Business Intelligence and Enterprise Performance Management (EPM) software, including Board, Power BI, Qlik, and ARXivar, to enhance decision-making and operational efficiency. The company’s headquarters is located in Santa Vittoria d'Alba, in the province of Cuneo, Italy.
Thanks to its flexibility and strong focus on innovation, Bios has experienced significant growth in recent years, now boasting over 200 employees and a client base of more than 500 companies in industries such as Automotive, Banking, Food and beverage, Manufacturing, and Utilities.

Bios Management operates across three main areas:

- Strategic consulting and innovation management, helping organizations drive business growth.

- Implementation of Business Intelligence, EPM, and Data Analytics solutions, optimizing decision-making processes.

- Automation and management of business relationships through Customer Relationship Management (CRM) and Human Capital Solutions.

This thesis project was carried out in collaboration with Bios Management S.r.l. specifically with the EPM Solution - Board division. The project focused on developing a business reporting model to simplify and optimize an organization's decision-making processes.

6.2 Process flow

Having defined the primary purpose of the application and the client's requirements, the design phase can begin. Creating the data model is the most critical and complex phase of the project, which involves the development of the calculation for the cost and FTEs (Full-Time Equivalents) of each employee within the budgeting process.

The first task, as discussed in the previous sections, is defining the time range. The data of interest concerns 2024 and 2025; however, to anticipate potential changes to the analysis years, it is customary to include a buffer for both the start and end years. Specifically, it was decided to start from 2015 for the beginning year and extend to 2025 for the end year. The greater backward extension for the start year is because any future adjustment to this would empty all the cubes in the data model, whereas any forward adjustment to the end year would not result in data deletion.

The temporal entities considered for the analysis are Month and Year. Figure 28 shows the relationships between the temporal entities in the model.

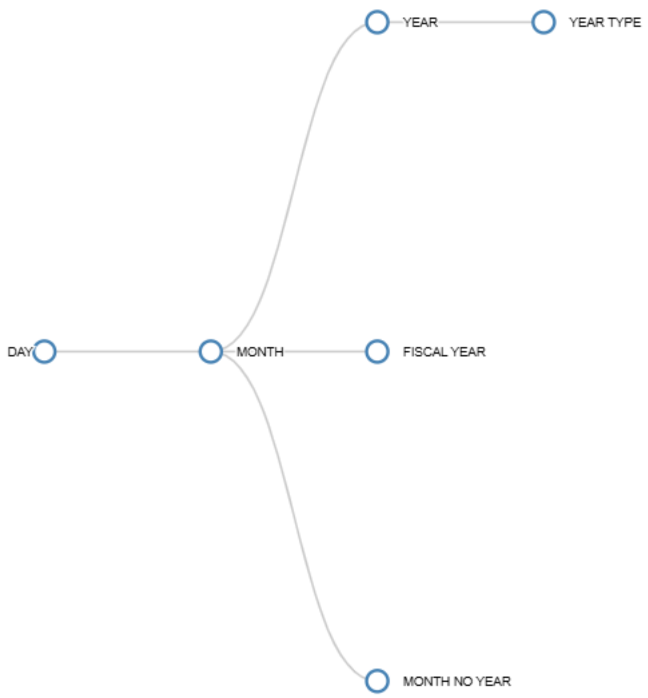

Image 28- Relationships between the temporal entities of the model

6.3 Entities, Relationships, and Cubes

For the Planning process, a dedicated data model named 'PLANNING HR' was created to acquire and structure the data to build the project capsule.

The data is divided into:

- Master Data: Codes and descriptions of the entities that will form the dimensions of the cubes (e.g., company, employee, etc.).
- Value Data: Numerical data that populates the intersection of entities within the cubes (e.g., the values of the value of employee costs for the Company).

6.3.1 Master Data

Three entities represent the root nodes of the main relational trees in the Planning data model, and they are graphically represented in Figures 29, 30,31, and 32. These are:

- Employee: This is the main entity, as this is an application designed to monitor the flow of employees within the company. The association tree, as can be seen, is quite complex because it considers all the demographic information that can be considered to tag the data. To ensure that the end user can make modifications to each related entity, a standalone replica of each entity has been created.

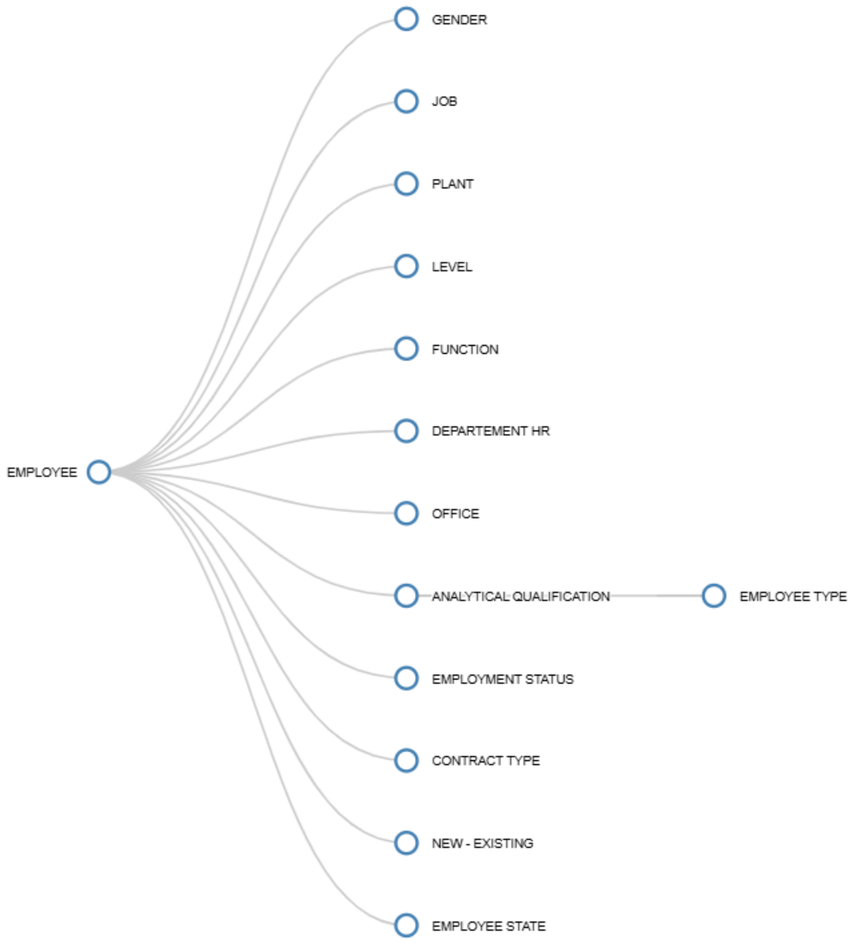

Image 29- Employee

- Pay item: refers to a specific component of an employee's compensation within a payroll system. It represents a category or type of payment or deduction

included in an employee's salary or wage calculation. Pay items are essential for breaking down and structuring an employee's compensation package.
In this specific case, it is related to a code set typically used to categorize pay items into macro classes.

Image 30- Pay Item

- Scenario: It is the entity through which the historicized budget scenario is identified and aggregated by type and is essential for saving, visualizing, and comparing the different versions of the planning created.

Image 31- Scenario

6.3.2 Value Data

After building the entities and their respective relationships, it was possible to proceed with the creation of the cubes. Each cube will be assigned a specific structure, meaning that its analysis dimensions are represented by the entities.

Cube	Structure
BDG001 – Planning Year [DE]	Year
BDG001 – Act Reference Month [DE]	Month
BDG013 – Mesi Aperti [DE]	Month no Year
BDG010 – MTX Pay Item , Code Set [DE]	Pay Item , Code Set
BDG002 – FTE Existing	Month, Employee
BDG004 – COST New Employee [SI]	Month, Employee, Company, Pay Item
BDG003 – FTE New [SI]	Month , Employee
BAN001 – Employee, CDC	Employee, Cost center

BAN002 – Employee, Analytical qualification	Employee, Analytical qualification
BAN003 – Employee, Function	Employee, Function SA
BAN004 – Employee, Department HR	Employee, Department HR SA
BAN005 – Employee, Contract Type	Employee, Contract type SA
BAN006 – Employee, Office	Employee, Office SA
BAN007 – Employee, Employment Status	Employee, Employment status SA
BDG005 – Cost [DE]	Month, Employee, Company, Pay Item
BDG004 – Cost Smart import	Month, Employee, Company, Pay Item
BDG012 – Percentuale contribute [DE]	Cost Type, Employee type SA
BDG012 – Percentuale TFR [DE]	Cost Type, Employee type SA
BDG014 – Cost Calculated	Month, Employee, Company, Pay Item
BDG009 – MTX Mese Festività	Month no Year
BDG022 – Tariffe [DE]	Cost Center
BDG027 - Headcount	Month, Employee, Company, Pay Item, Cost Center, Analytical qualification, Function SA, Department HR SA, , Contract type SA, Office SA, Employment status SA
BDG029 – Flag Scenario	Scenario
BDG026 - Scenario	Scenario
BDG020 - FTE	Month, Employee, Company, Pay Item, Cost Center, Analytical qualification, Function SA, Department HR SA, , Contract type SA, Office SA, Employment status SA
BDG017 – Cost	Month, Employee, Company, Pay Item, Cost Center, Analytical

	qualification, Function SA, Department HR SA, , Contract type SA, Office SA, Employment status SA

All the cubes that have "DE" in their name are in Data Entry, meaning the clients themselves will populate them with data entered in real-time into the platform.
Those with "SI" indicate that the data is uploaded via smart import, an object available in Board that allows you to directly upload an Excel or text file to populate a cube.

As described in paragraph 5, the next step in the analysis process is the data reading process. However, since this budgeting application relies on the actual data from the last closed month, the data is read through a load procedure that will be analyzed later. Alternatively, as mentioned above, it can be read via smart import, and the end user will only manually modify it at a later stage.

6.4 Procedure

As mentioned earlier, the key procedures for effective development are three:

- BDG001—Initialize FTE: This procedure is not particularly complex. Through calculations, or, in technical terms, data flow, the data is copied from the actual cubes to the months marked as open in the first cube dedicated to the FTE calculation, BDG002.
  In this step, only the data of employees already present in the system will be available. If new hires are planned, the data will be entered via smart import into a dedicated cube, namely BDG003.

- BDG003 – Initialize cost Festività, Contributi, TFR, temporary: this procedure, on the other hand, is somewhat the heart of the entire flow. As can be seen from the figures, it is quite long and detailed. According to the client's requests, the cost items in the code set must be calculated according to specific drivers and formulas.
  The BDG cost associated with each employee is written in the cube BDG014.

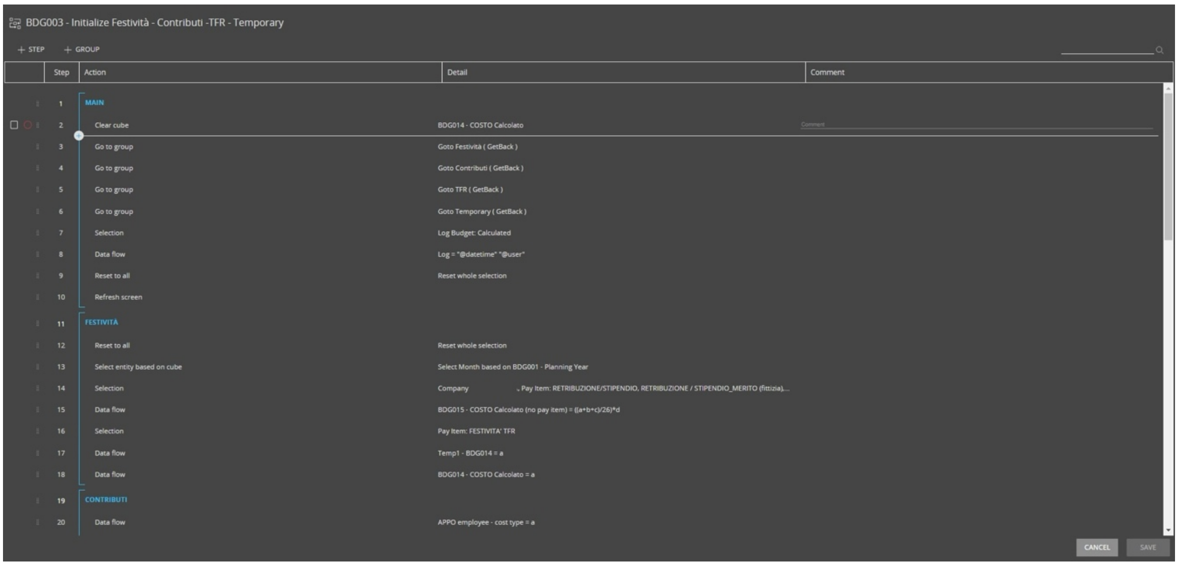

Image 32- BDG003 – Initialize cost Festività, Contributi, TFR pt1

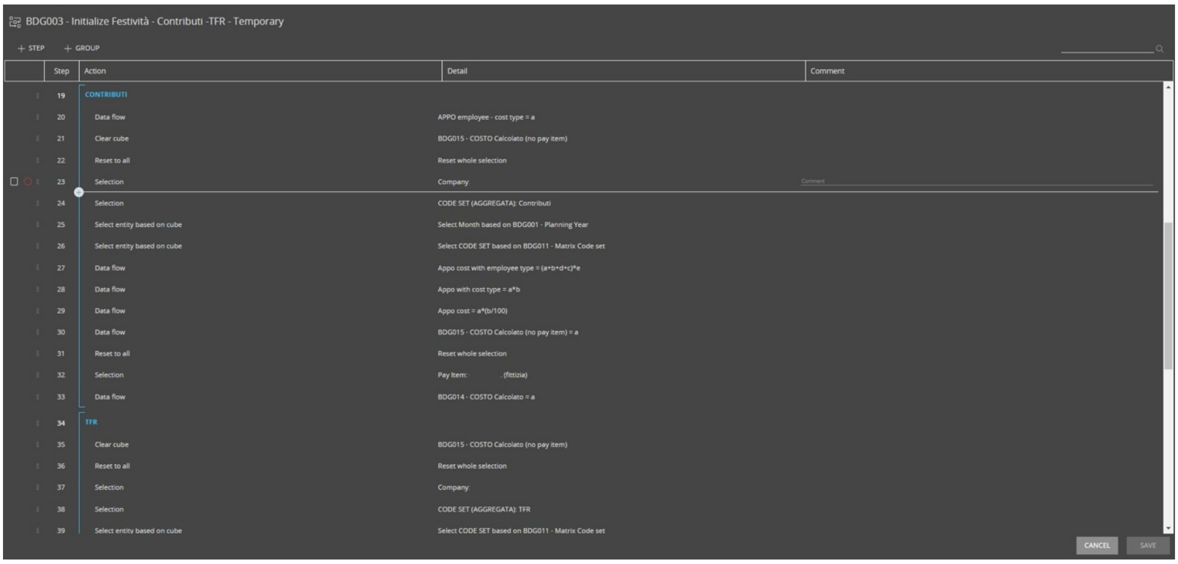

Image 33- BDG003 – Initialize cost Festività, Contributi, TFR pt2

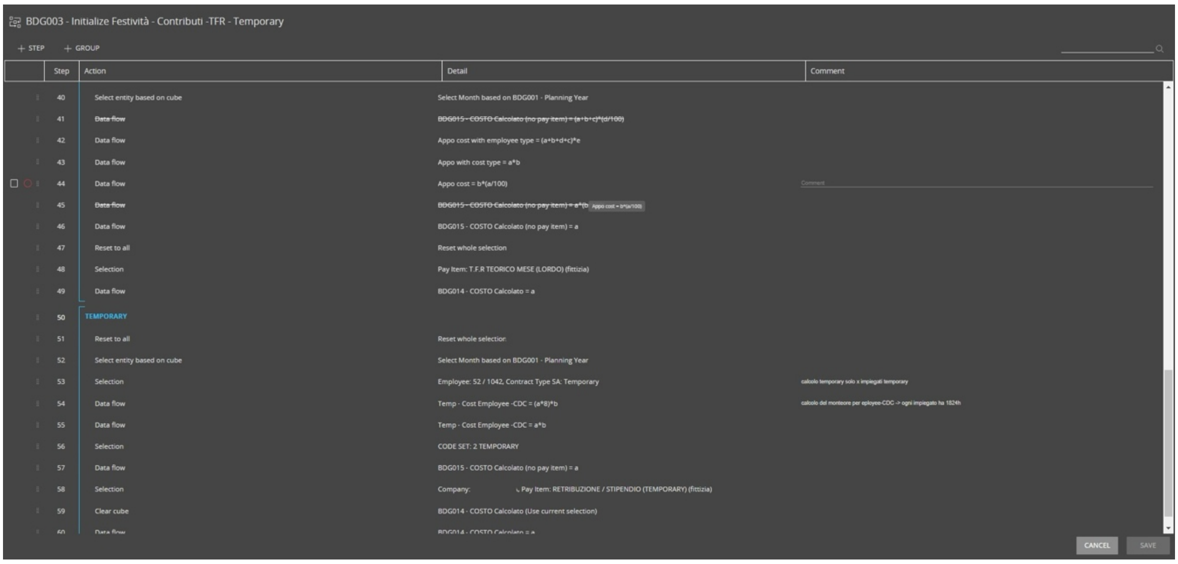

Image 34- BDG003 – Initialize cost Festività, Contributi, TFR pt3

In steps 44 and 29 of the procedure, the precise calculation of costs related to contributions and severance pay (TFR) takes place. These calculations are based on a percentage allocation manually entered by users, which determines the allocation percentage for each employee type.

	% Contributi
- PRODUCTIVE COST	
Operai Diretti	33.68%
Operai Indiretti	33.43%
Personale Fisso	32.12%
- NON PRODUCTIVE COST	
Operai Diretti	
Operai Indiretti	33.86%
Personale Fisso	32.42%
- SALES COSTS	
Operai Diretti	
Operai Indiretti	
Personale Fisso	
- OTHER	
Operai Diretti	
Operai Indiretti	
Personale Fisso	

	% TFR
- PRODUCTIVE COST	
Operai Diretti	6.45%
Operai Indiretti	6.55%
Personale Fisso	6.64%
- NON PRODUCTIVE COST	
Operai Diretti	
Operai Indiretti	6.44%
Personale Fisso	7.36%
- SALES COSTS	
Operai Diretti	
Operai Indiretti	
Personale Fisso	
- OTHER	
Operai Diretti	
Operai Indiretti	
Personale Fisso	

Image 35- Percentage allocation

- BDG002—Initialize cost PY & Last month: This procedure allows the selected code sets to report data from the previous year or the most recent available month.

All of these procedures allow us to calculate the data that is then presented in the reports, which are analyzed in more detail in the following paragraph.

6.5 Capsule HR Planning

Once the model structure is defined, the next step is to create the Capsule. This represents the output of the entire process, as it is what the client will view and interact with to perform the analyses of interest. Therefore, it is necessary to build an environment that is as intuitive and user-friendly as possible, with linear workflows and data visualization tools suited to each type of analysis.

The first screen that appears when entering the environment dedicated to the HR budget is shown in Figure 35, a homepage divided into 4 sections: setting, FTE, cost, and scenario.

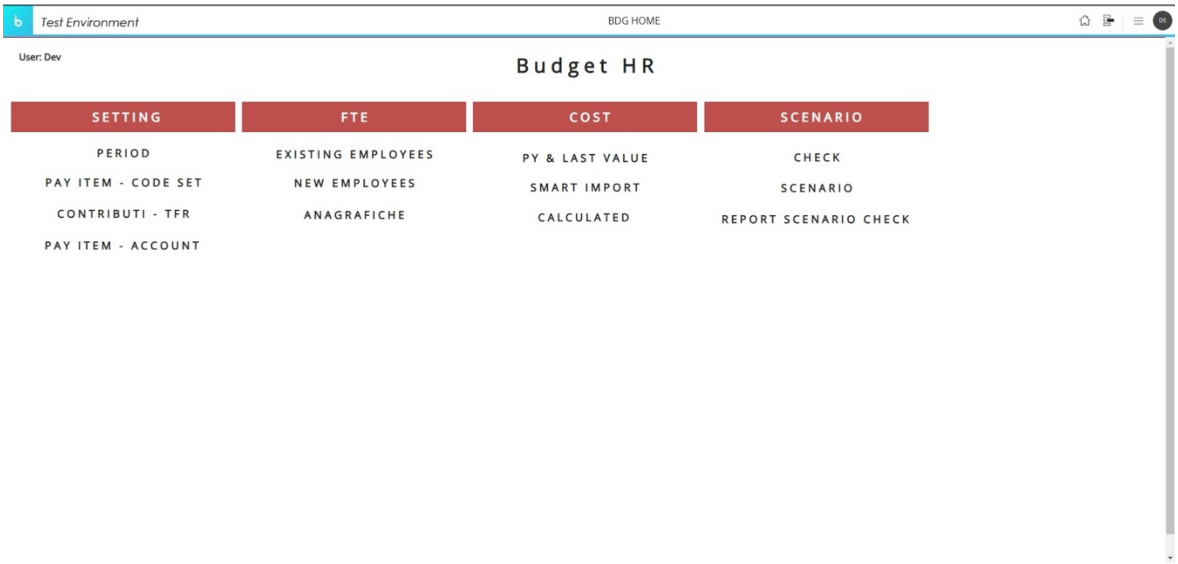

Image 36- Homepage

6.5.1 Setting

The Settings section is necessary for setting up and controlling the entities and data underlying the consolidation process. In the following submenu, as shown in Figure 36, you will find the data control and modification screens.

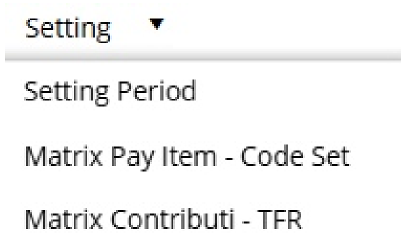

Image 37- Submenu of the Settings section

Below is the first screen of the time settings, where the first step is to select the year for which planning is to be done. In the second table, the last month in which the data was finalized is displayed, which will serve as the starting point for the model. In the far-left tab, the remaining open months of the current year are shown, for which the budget is to be planned.

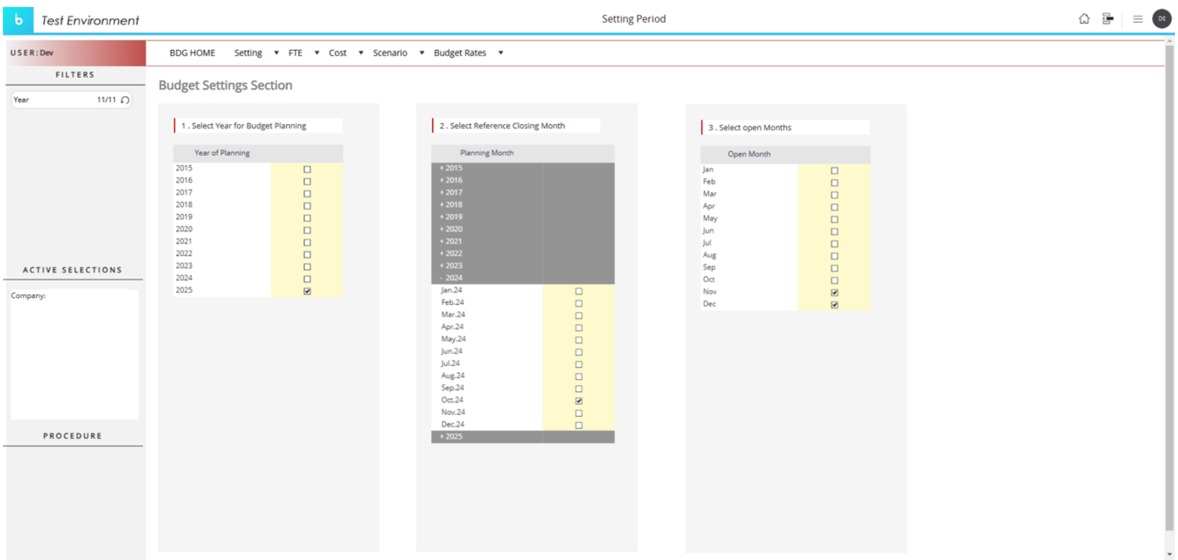

Image 38- Setting period screen

To proceed with the process, the user needs to provide two additional configurations. The first, visible in the Matrix Pay Item - Code Set screen, provides the essential elements for cost calculation, which takes place through the procedures described in paragraph 6.3. This report is divided into three sections:

- First section: Through a Board object called Entity Editor, the user has the option to manually insert a new occurrence within the Pay Item entity, if necessary.
- Second section: Using a specific layout setting called Data Entry (which is recognizable by the pinkish color of the cells), the user can independently link each Pay Item to a specific Code Set.
- Third section: Configured in the same way as the second, it allows each Code Set to be linked to a specific Driver of calculation.

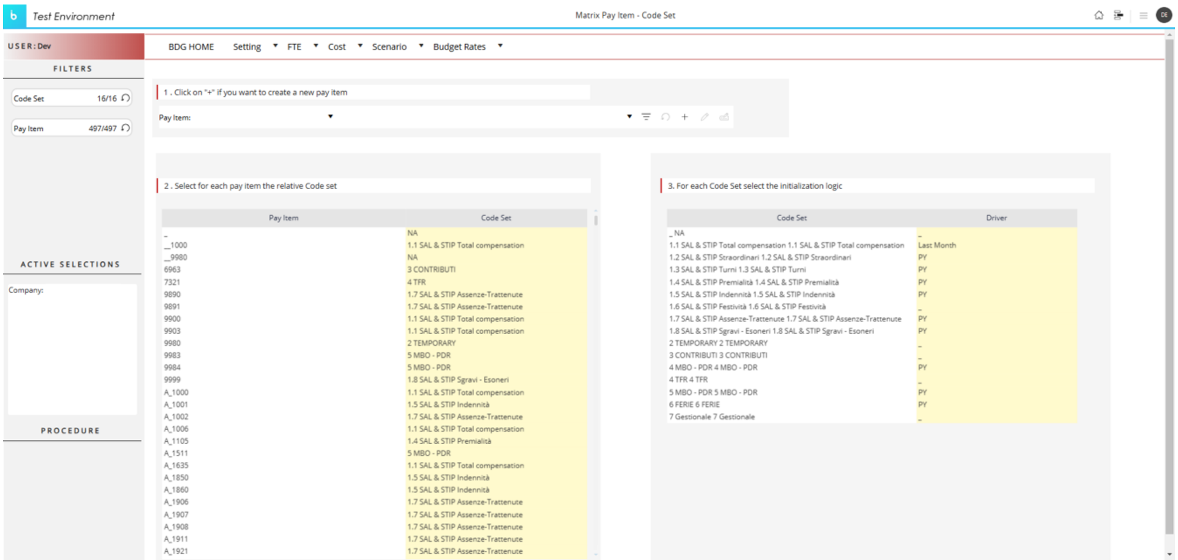

Image 39- Matrix Pay Item-Code set

The same basic logic applies to the last settings screen, where a matrix is created to identify the Code Sets tagged for contribution calculations and those tagged for severance pay (TFR) calculations.

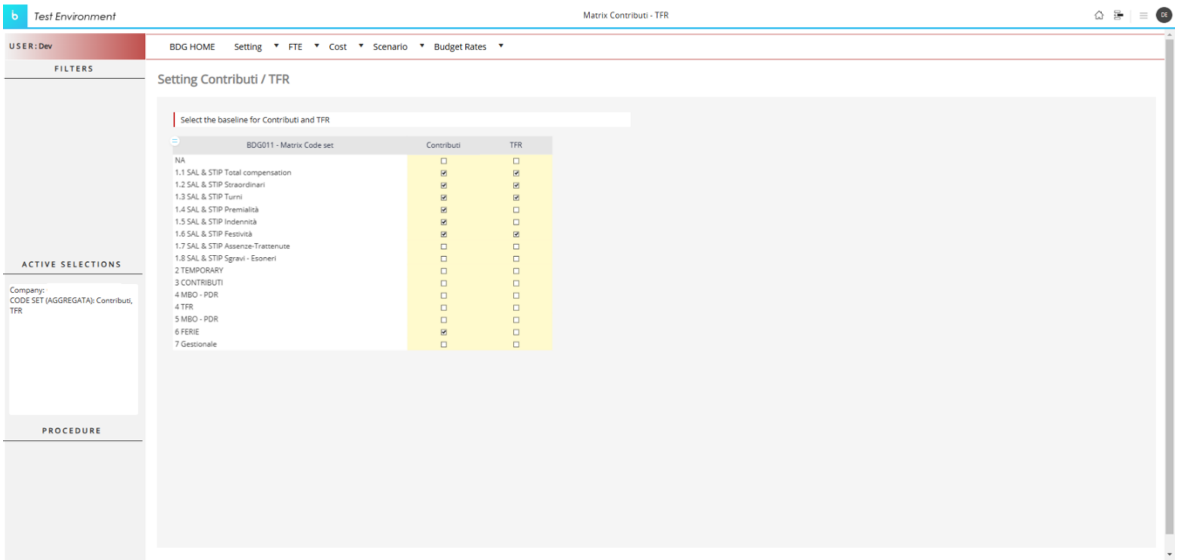

Image 40- Matrix Contributi - TFR

6.5.2 FTE And Cost

In this section, the number of FTE, an abbreviation for Full-Time Equivalent, is tracked and calculated. This HR metric represents the workforce employed about a full-time employee (considered as "1"). (47)

As a first step, the system analyzes the employees already present, displaying the number of FTE each employee had in the previous year for each month in the planning period. The cell colors immediately indicate that the entire table is in data entry mode, meaning it can be modified if necessary for the new year's budget.

Additionally, if an employee is marked as "OUT" in the "Employee State" column, the procedure described in Section 6.3 (located at the bottom left) will assign an FTE value of 0 to that specific employee for the entire planning year. The employee will no longer be included in the workflow.

For privacy reasons, employees are identified only through a unique identification code assigned to each of them.

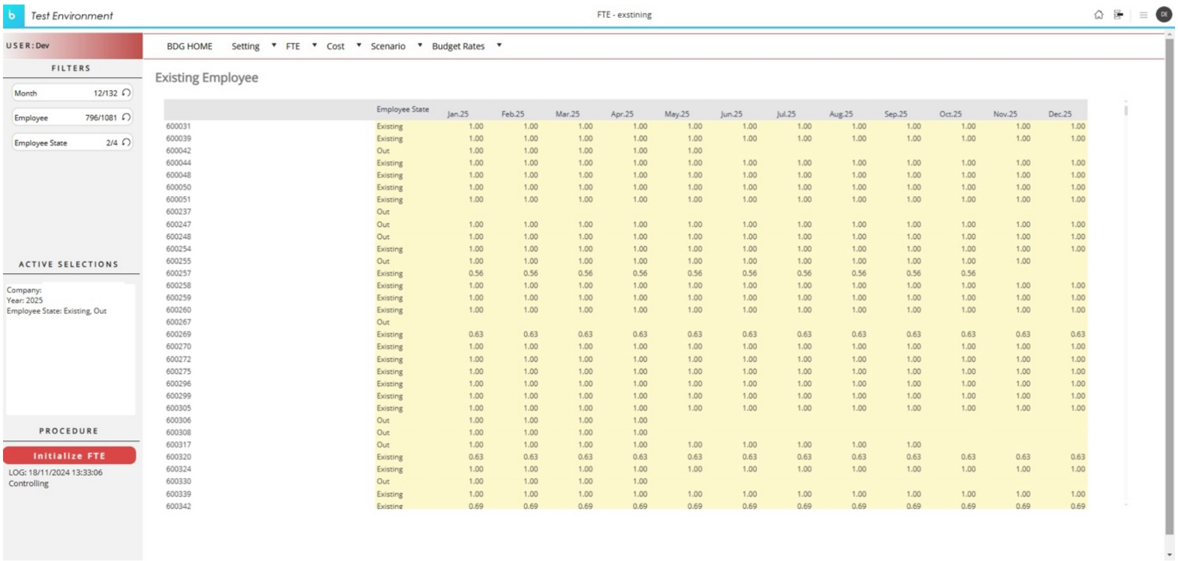

Image 41- FTE Existing

Once the analysis of employees already in the system is complete, the user can make projections by adding all individuals expected to join the company in the future. These individuals will be tagged as new employees, and their profiles, along with the associated budgeted costs, can be entered through these screens using the smart import feature.

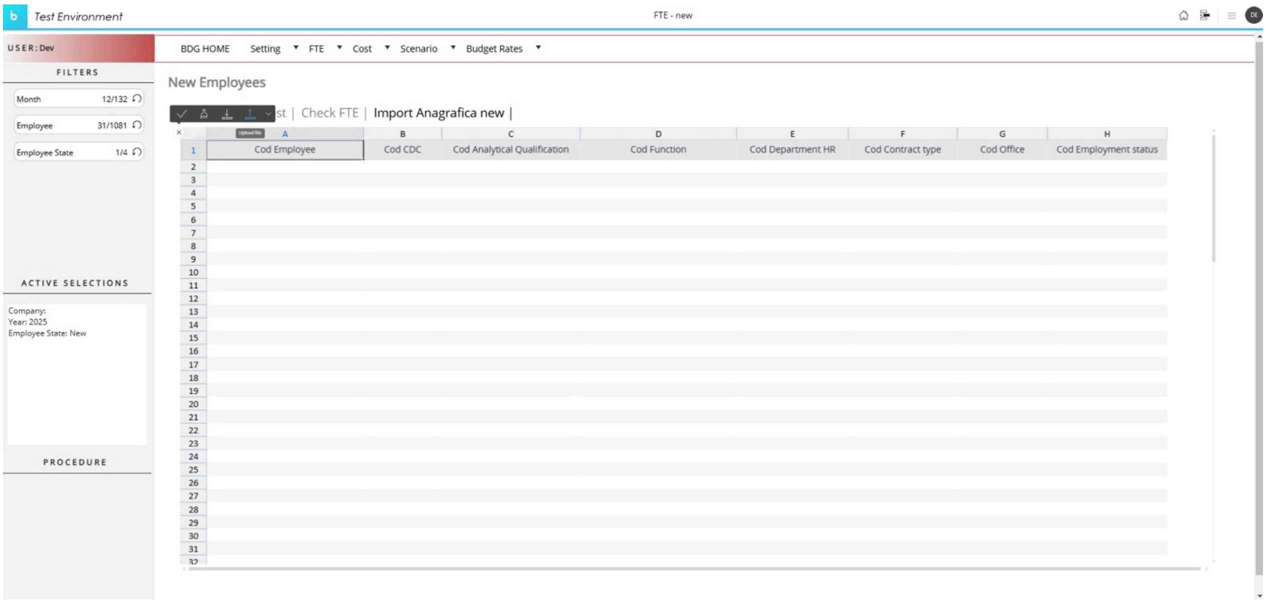

Image 42- Smart import for New employee

To use the smart import as a data source, which can be done either by uploading an XLS file or through manual entry, it must first be designed. Figure 42 shows an example of a smart import layout.

This layout must include all the entities to be mapped and, finally, the cubes to be populated (which must have the same entities listed above as axes). For each entry, the input column must be specified, and a clear rule needs to be defined. For entities, the rule can be set to "discard," meaning any occurrence that is not present in the system will be excluded and not added to the model, or "add," which does the opposite by including those occurrences.

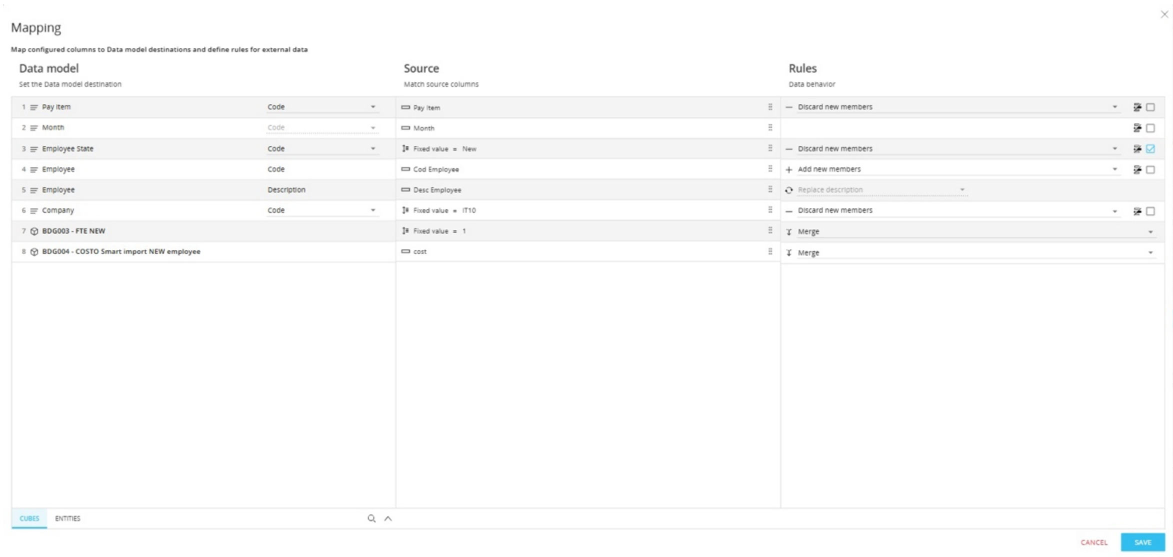

Image 43- Smart import setting

After analyzing the FTE section, the flow focuses on the allocation of costs for each employee. As mentioned earlier, two specific procedures are dedicated to this part: one for cost allocation based on PY (Previous Year) drivers and Last Month, and the other for calculating contributions, severance pay (TFR), and holidays. The images below show the results of the procedures discussed above.

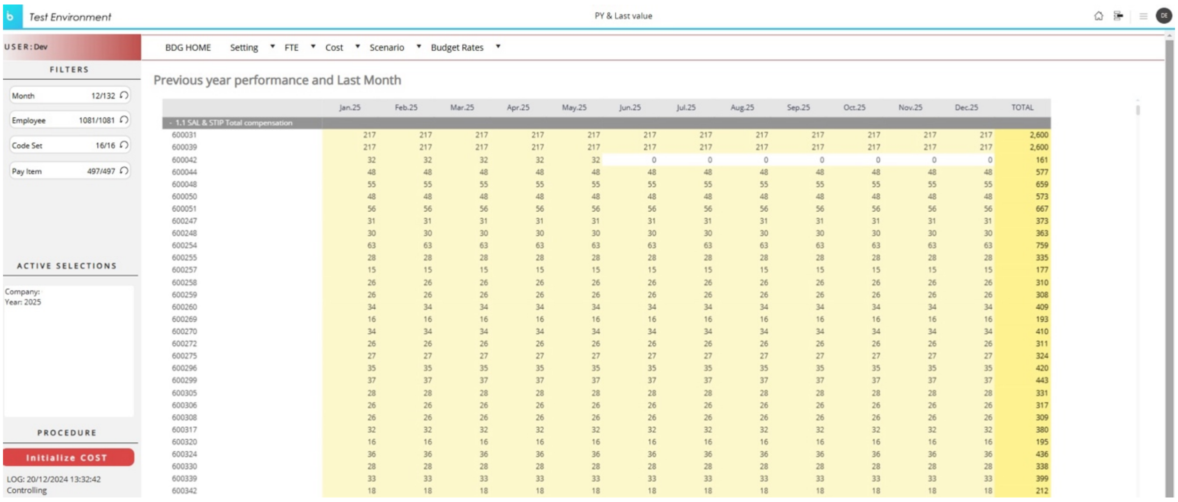

Image 44- PY and Last month's cost

Calculated	Jan.25	Feb.25	Mar.25	Apr.25	May.25	Jun.25	Jul.25	Aug.25	Sep.25	Oct.25	Nov.25	Dec.25	TOTAL
1.6 SAL & STIP Festività											785		785
2 TEMPORARY	1,217	1,281	1,345	1,281	1,281	1,281	1,473	512	1,281	1,409	1,217	833	14,410
3 CONTRIBUTI	8,380	9,223	9,254	8,964	9,302	9,597	9,180	5,457	9,214	9,466	9,617	7,441	105,094
4 TFR	1,727	1,736	1,742	1,729	1,748	1,765	1,774	1,699	1,763	1,781	1,816	1,735	21,015
TOTAL	11,324	12,240	12,341	11,974	12,331	12,643	12,427	7,669	12,258	12,656	13,435	10,008	141,304

Image 45- cost Festività, Contributi, TFR, temporary

6.5.3 Scenario

In the "Scenario" section, the user has the option to create a new working scenario in which to save the created planning.

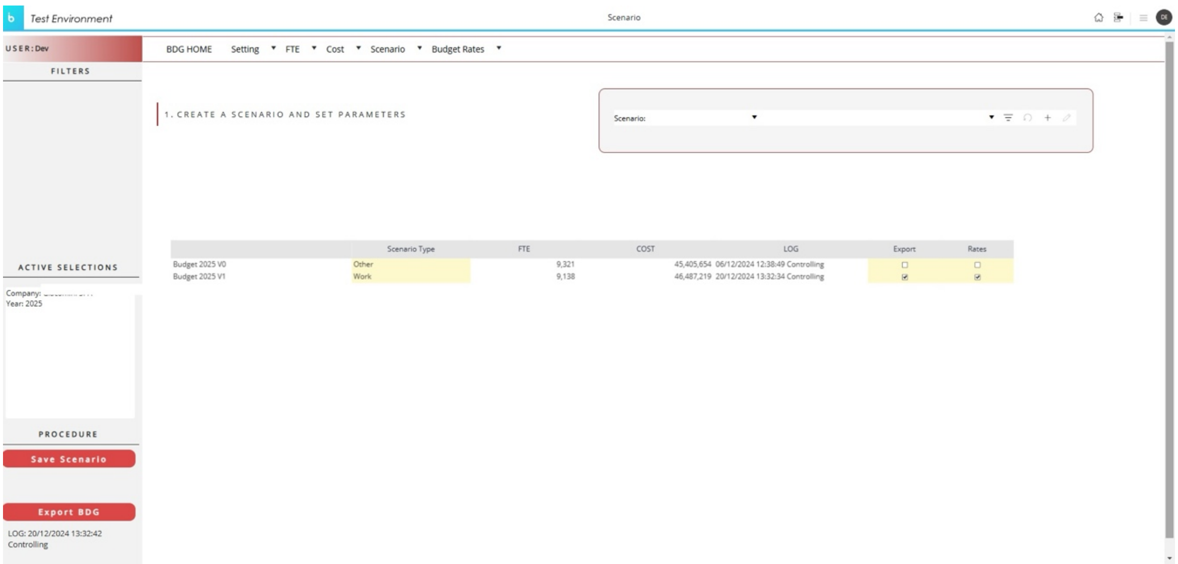

Image 46- Scenario

Through the section in the top, the user can create a new occurrence for the "Scenario" entity, allowing them to save multiple revisions and budget forecasts, but not only that.

Thanks to this screen and the data view below, each scenario can be assigned a "Scenario Type" label. For the following, the user can assign the following items:

- Work: This is the scenario to be used in the saving procedure to store all the data currently present in the planning screens.
- OTHER: This is a scenario that is not to be used in the report.

Finally, through the "Save scenario" procedure, which the user can initiate via the corresponding button, the program processes all the data from the previous steps and saves it in the final cube under the scenario marked as "work." If the "Export" column is also flagged, the Board procedure will export it and download it locally to the user's device.

6.6 Benefits of BI implementation in Corporate Environment

Thanks to the implementation of the BI solution, the company has achieved significant improvements in several areas.

Aspects	Before BI	After BI
Data access	Reports were generated with delays of several days.	Real-time data access through interactive dashboards.
Data quality and reliability	Data was fragmented across multiple systems and prone to errors.	Centralized and validated data in a single, reliable repository.
Analysis Time	Extracting and analyzing data took hours or even days.	Instant analysis using OLAP tools for faster insights.
Decision support	Decisions were primarily based on experience and intuition.	Data-driven approach with KPIs, predictive analytics, and simulations guiding strategic choices.

Operational efficency	Large use of Excel and manual processes, leading to inefficiencies.	Automated and optimized workflows, reducing errors and improving productivity.

With the integration of Business Intelligence, the company has transformed its approach to data management, moving from fragmented and delayed reporting to real-time insights, improved accuracy, and data-driven decision-making.

7 Software comparison

Nowadays, the market offers a wide range of business intelligence software, each with different technical features. The strategic consulting firm Gartner Inc. is renowned for conducting qualitative comparisons to evaluate these products. This helps guide entrepreneurs in choosing technology products that best suit their business needs.

Gartner's Magic Quadrant, or Magic Quadrant (MQ), analyzes the main players in each sector or service market with proprietary qualitative analysis methods. Using market trends, such as direction, maturity, and participants.
This methodology is graphically represented by a table whose competitive value of the main technology providers in rapidly growing markets is divided into 4 categories: Leaders, Visionaries, Niche Players, and Challengers. (42)

In Figure 28, the results of the 2021 research are shown, listing the 20 best analytics and business intelligence software and Board is between the niche players.

Image 47 - Gartner Quadrant 2021 for solution of Business Intelligence and Analytics

In 2023, it was named by the renowned consulting firm as a Leader in the Magic Quadrant for Financial Planning and Analytics (FP&A), as shown in figure 29 (43).

Figure 1: Magic Quadrant for Financial Planning Software

Image 48 - Gartner Quadrant 2024 for Financial Planning and Analytics

The study conducted by Gartner considers only the technical aspects, excluding the actual needs of the end users, who, not being IT professionals, have very different requirements. For this reason, to better understand the reasons that led Bios Management to adopt the Board platform, the Quality Function Deployment (QFD) methodology was used.

7.1 Quality function deployment

The Quality Function Deployment (QFD) is a system to translate customer requirements (CRs) into appropriate company requirements and technical features. (44)

The QFD is divided into four phases:

- Production Planning Matrix: phase of planning new product.
- Part Deployment Matrix: Detailed design of each component of the product.
- Process Planning Matrix: Design of the process that enables the realization of the identified technical characteristics.
- Process and Quality Control Matrix: Definition of the controls to be performed to establish the quality of the final product.

The first step to follow is the implementation of the House of Quality, which is a matrix describing the transition/link from a set of customer requirements (the “WHATs”) to a set of technical solutions related to the product/service of interest, to meet the customer requirements (the “HOWs”). (44)

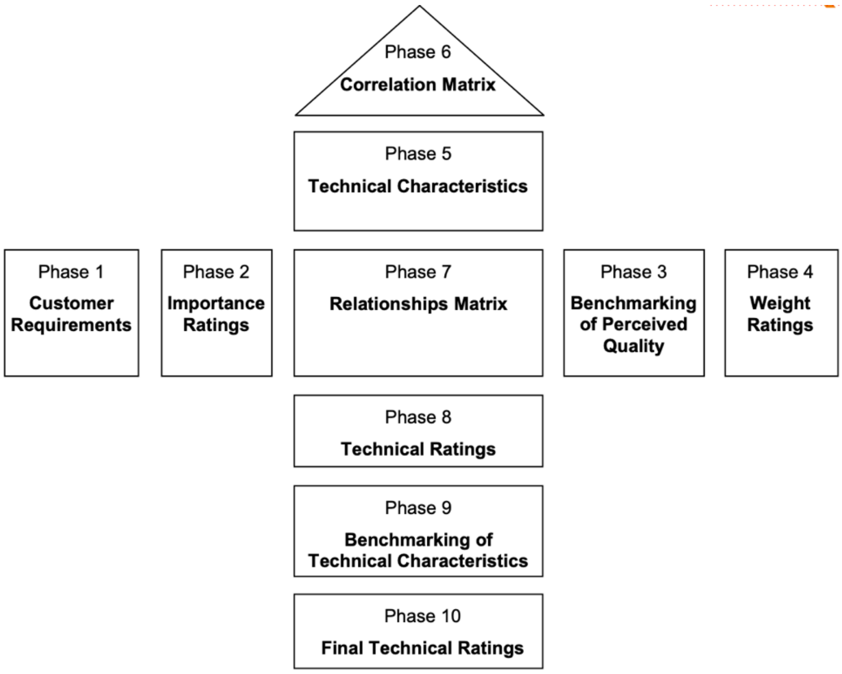

Image 49- Construction of the HOQ

The main steps for the implementation of the House of Quality are:

- Definition of customer’s needs
- Design requirements: transformation of customers’ needs into technical characteristics
- Competitor analysis: a detailed comparison with competitors through benchmarking that cross-references customer needs and technical characteristics (Relationship matrix).

7.1.1 Customer Needs

Table 1 represents the most important customer needs based on analyses and a survey conducted by Board. (45)

Each requirement is given a "degree of importance" coefficient based on a 5-point ordinal scale, where 0 represents the lowest value, and five is the highest, as determined by the customer. Alongside this, a "relative importance" value is calculated, reflecting the percentage weight of the requirement to the overall importance of all requirements. (44)

The “relative importance” is established by:

$$C_i = \frac{w_i}{\sum_{j=1}^{n} w_j}$$

Where C_i is the relative importance of the i-th requirement, w_i , the degree of importance of the i-th requirement, and n is the total number of requirements. (44)

Customer Needs	Description	Degree of importance	Relative importance
Fast system	The system needs the best possible optimization, in computational and functional terms	3	12%
Real-Time Data Insights	The ability to access up-to-data information for quick and accurate reporting, empowering agile responses to market changes.	4	16%
Output reliability	The system must return reliable and meaningful output data for the user's ultimate purposes	4	16%
User friendly and customize	The system must be user friendly and tailored to the customer's requests	2	8%
User profiling ,security and coworking	User hierarchization that allows to act simultaneously on the software in different ways	3	12%
Seamless System Integration	The capability to integrate effortlessly with existing systems to ensure a connected and consistent data ecosystem	1	4%
Dynamic and adaptable system	The system must be dynamic and adaptable to changes that the user requests	2	8%
Cost and Efficiency Optimization	Solutions that enable better resource allocation, cost control, and process efficiency to drive business value.	1	4%
Performance Tracking and	The ability to track performance against key indicators, ensuring	5	20%

KPI Monitoring	accountability and alignment with organizational goals.		

Table 1 – Customer Needs

Thanks to this first analysis, the main customer requirements are Performance Tracking and KPI Monitoring, Real-Time Data Insights, and Output reliability.

7.1.2 Competitive Benchmarking on Customers' Requirements

Benchmarking analysis allows us to understand the perception of the product through the CRs and to analyze how our competitors match up to the CRs of our product. (44)

For this part, the standard practice requires data collection to be carried out by having a sample of users who use all the competitors' products under analysis and evaluate the level of satisfaction that the product offers for each customer requirement.
Since it was not possible to conduct the described data collection, the evaluations for each customer requirement were determined by calculating the sum of the scores in Gartner's research for each software characteristic influencing that requirement, weighted according to the correlation represented in the relationship matrix.
To enable comparison, all scores were then normalized to the [0;5] range.

The evaluation ($V_{n,i}$) of the n-th competitor for the i-th customer requirement is performed by calculating:

$$V_{n,i} = \sum_{j=1}^{m} r_{ij} \cdot PG_{nj}$$

Where m is the total number of technical characteristics, r_{ij} is the value of the correlation between the j-th technical characteristic and the i-th customer requirement, and PG_{nj} is the score assigned by Gartner to the n-th competitor for the j-th technical characteristic. To normalize the evaluation $V_{n,i}$, a proportion is applied such that:

$$V_{n,i} : V_{tot,i} = P_{n,i} : 5$$

Where $V_{tot,i}$ is the maximum evaluation a competitor can achieve for the i-th customer requirement and is defined as:

$$V_{tot,i} = \sum_{j=1}^{m} r_{ij} \cdot 5$$

Where the variables m r_{ij} take the same values as in the previous expression, and 5 is the maximum score a competitor can receive for a technical characteristic according to Gartner's analysis.

The score $P_{n,i}$ assigned to each software is therefore given by:

$$P_{n,i} = \frac{V_{n,i} \cdot 5}{V_{tot,i}}$$

Below, the score for Board is calculated for the "Speed" requirement as an illustrative example. The data is shown in Table 4.

Customer Requirments / Technical Characteristics	Configurable Models	Scenario Modelling	Publishing Analytics Content	Management Insights and Dashboarding	Workflow automation	User Experience/ Governance	Pricing Flexibility	Availability of 3rd-Party Resources	Ease of Deployment	Implementation strategy	Ease of Integration using Standard APIs and Tools
Speed		○	△	○		○			○		
Board	4,7	4,6	4,1	4,5	4,5	4,5	4,4	4,3	4,5	4,3	4,4

Table 4 – Board's score for the "Speed" requirement

Board is the competitor $i = 0$, and "Speed" is the requirement $n = 1$.

$$V_{1,0} = 3 \cdot 4{,}6 + 1 \cdot 4{,}1 + 3 * (3 * 4{,}5) = 58{,}4$$

$$V_{tot,1} = (3 + 1 + 3 + 3 + 3) \cdot 5 = 65$$

$$P_{1,0} = \frac{58{,}4 \cdot 5}{65} = 4{,}5$$

Four competitors were identified, and the same procedure was applied to each. The results are shown in Table 5.

The confrontation of the current perception of our current model versus the competitors' permitted us to set the target as the maximum value among those identified in the customer competitive assessment. (44)

	Customer Competitve Assesment								
	CURRENT MODEL	IBM planning analitics	KEPION	ORACLE	SAP	TARGET	IMPROVEMENT RATIO	ABSOLUTE WEIGHT	RELATIVE WEIGHT
Speed	4,5	4,2	4,0	4,5	4,3	4,5	1,00	3,0	11,9%
Live Insights	4,3	4,2	3,9	4,4	4,2	4,4	1,02	4,1	16,1%
Accuracy	4,4	4,2	3,9	4,4	4,2	4,4	1,00	4,0	15,8%
Usability	4,5	4,4	4,0	4,6	4,3	4,6	1,02	2,0	8,1%
Access Control	4,5	4,3	4,3	4,6	4,2	4,6	1,02	3,1	12,1%
Integration	4,1	3,8	3,4	4,1	4,1	4,1	1,01	1,0	4,0%
Flexibility	4,5	4,2	3,8	4,5	4,4	4,5	1,02	2,0	8,0%
Optimization	4,5	4,0	4,7	4,5	4,0	4,7	1,05	1,1	4,2%
Tracking	4,5	4,4	3,7	4,4	4,2	4,4	1,00	5,0	19,8%
								25,3	100,0%

Table 5 – Competitors Benchmarking

Then the improvement ratio was calculated by dividing the target level by the satisfaction level related to the current model (Board). (44)

$$\text{Improv. ratio} = \frac{\text{Target level}}{\text{Satisfactio level of our model}}$$

Finally, the Absolute weight and the relative weight can be evaluated, respectively these two indicators represent the overall importance of that specific CR and the percentage of if to make it more understandable. (44)

$$\text{Absolute weight} = \text{degree of importance} * \text{improvement ratio}$$

$$\text{Relative weight (CRi)} = \frac{\text{Absolute weight (CRi)}}{\sum \text{Absolute weight (CRi)}}$$

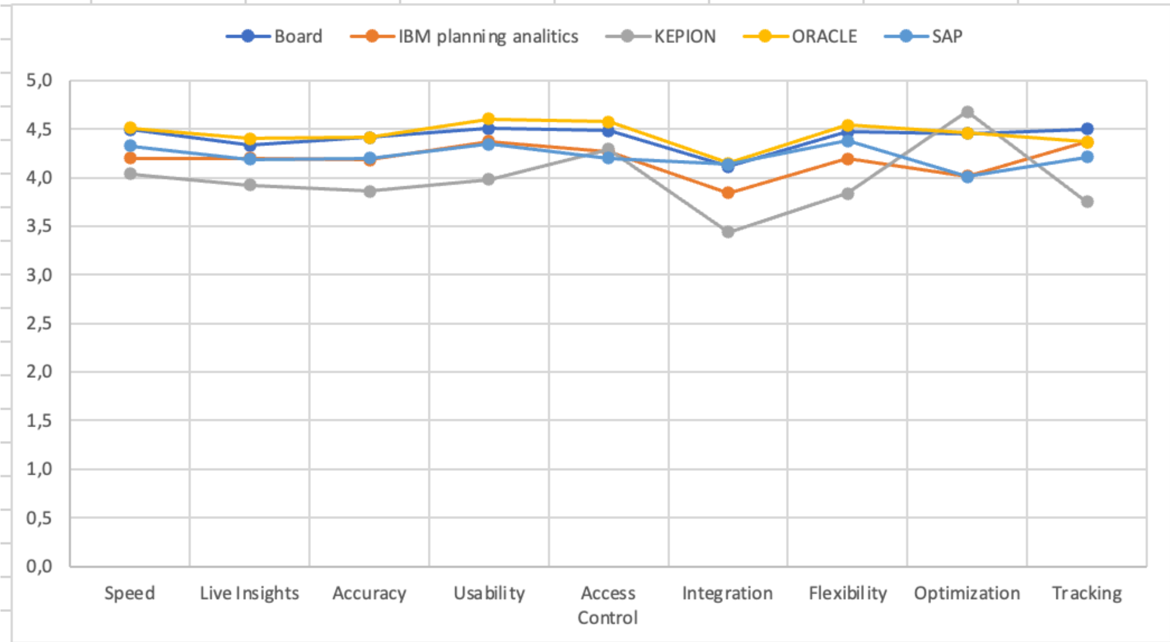

Image 50- Chart of the results from the "Customer Competitive Assessment" table

The chart shows that no competitor clearly dominates, and the Board application tends to position itself in the upper-middle range of the interval.

7.1.3 Technical Characteristics

Technical characteristics are engineering and design requirements that a product must have to satisfy the customer's needs.
Each CR should be associated with one or more technical characteristics that should be: (44)

- Clearly explained
- Objective
- Clearly /objectively measurable (suitable measuring procedure and unit);
- Related to a specific preference sense (↑ or ↓)

For the definition of the technical characteristics, the analysis conducted by Gartner was referenced. For the search "Gartner Quadrant 2024 for Financial Planning and Analytics", the following characteristics were defined and evaluated: (46)

- Configurable models: financial planning models that can be easily customized to meet specific business needs without complex software changes.
- Scenario modeling involves creating and analyzing different financial scenarios to evaluate potential outcomes and make informed decisions based on varying assumptions and variables.
- Publishing Analytics Content: methods of publishing and sharing analysis content.
- Management Insights and Dashboarding: tools for creating dashboards for data analysis and insights monitoring.
- Workflow automation: automates repetitive processes to improve efficiency, accuracy, and consistency in business operations.
- User Experience/ Governance: ease of use ensuring data integrity, compliance, and security through policies and controls.
- Pricing Flexibility: flexibility in software cost
- Availability of 3rd-Party Resources: possibility to use third-party resources.
- Ease of Deployment
- Implementation strategy: possibility to integrate analytics tools to optimize business strategy.
- Ease of Integration using Standard APIs and Tools: simplicity and efficiency of connecting software solutions with existing systems through standardized application programming interfaces (APIs) and integration tools, minimizing disruption and maximizing compatibility.

Not all the characteristics listed above are physical, but the purpose of the comparison is to establish why Board was chosen to develop the thesis project.
In its analysis, Gartner assigns a score from 0 to 5 to each listed characteristic, where 0 represents the minimum score and 5 the maximum. These data are shown in the middle part of the house of quality.

	Configurable Models	Scenario Modelling	Publishing Analytics Content	Management Insights and Dashboarding	Workflow automation	User Experience/ Governance	Pricing Flexibility	Availability of 3rd-Party Resources	Ease of Deployment	Implementation strategy	Ease of Integration using Standard APIs and Tools
Board	4,7	4,6	4,3	4,5	4,5	4,5	4,4	4,3	4,5	4,3	4,4
Competitor #1: IBM Planning Analitics	4,7	4,5	4,2	3,9	4	4,3	4	4,1	4,1	4,4	4,1
Competitor #2: Kepion	4,6	4,1	3,3	4	4,4	4,3	5	3	4	4,4	4
Competitor #3 : Oracle	4,7	4,7	4	4,5	4,5	4,6	4,4	4,5	4,4	4,6	4,4
Competitor #4: SAP	4,4	4,4	4	4,3	3,9	4,2	4,1	4,4	4,5	4,2	4,4

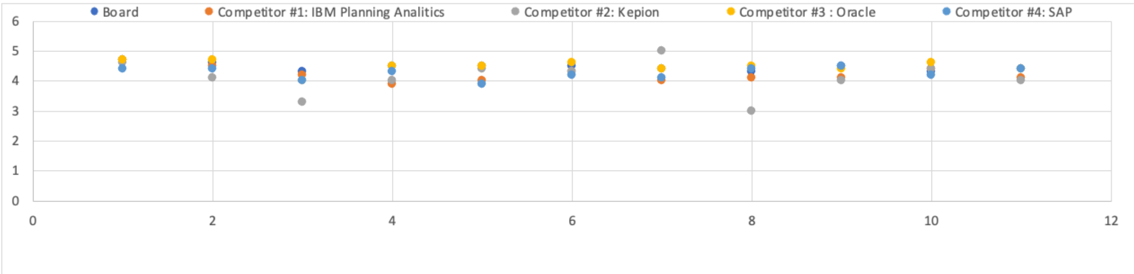

Table 2 – Matrix of Technical Requirement

The graph shows that despite the different positioning in Gartner's quadrants, the evaluations do not differ significantly from each other and remain within the domain [3; 5].

Also from this analysis, as mentioned above competitors clearly dominate, and the Board application tends to maintain the same position.

After identifying the Technical Characteristics, the Relationship matrix is constructed, assigning values that reflect the strength of the relationship between Customer Requirements (CRs) and Technical Characteristics (TCs) according to this legenda: (44)

● = Strong relationship

○ = Intermediate relationship

Δ = Weak relationship

[ø] = No relationship

Image 30- Relationship

Below is the representation of the relationship matrix.

Customer Requirments / Technical Characteristics	Degree of importance	Relative importance [%]	Configurable Models	Scenario Modelling	Publishing Analytics Content	Management Insights and Dashboarding	Workflow automation	User Experience/ Governance	Pricing Flexibility	Availability of 3rd-Party Resources	Ease of Deployment	Implementation strategy	Ease of Integration using Standard APIs and
			A	B	C	D	E	F	G	H	I	J	K
Speed	3	12,0%		○	△	○		○			○		
Live Insights	4	16,0%		●	●	●						●	
Accuracy	4	16,0%		●	●	●	○						
Usability	2	8,0%	●	○	○			●		●			△
Access Control	3	12,0%					△				△	△	
Integration	1	4,0%		○						●	●		●
Flexibility	2	8,0%	○	△		△				△			△
Optimization	1	4,0%					●	△	●				
Tracking	5	20,0%	○	●	●								
TOTAL	**25**	**100%**											

Table 3 – Relationship Matrix

The Independent Scoring Method (ISM) now is used to prioritize the technical characteristics, the most important TCs are those that impact a larger number of customer needs and are related to the most important ones because they have more impact on customers.

The first step of ISM is to calculate the absolute weight of each TCs, multiplying the relationship-matrix coefficients by the relative weight of the corresponding customer requirements and then the results are summed for each column.

$$Absolute\ Weight\ (TCj) = \sum_{\forall i} [r_{ij} * Absolute\ relative\ weight\ (CRi)]$$

The second step is to calculate the relative importance, which is given by dividing (in order) the absolute weight by the sum of all absolute weight.

$$Relative\ weight\ (TCj) = \frac{Absolute\ weight\ (TCj)}{\sum_{\forall j} Absolute\ weight\ (TCj)}$$

Absolute weight	2,2653	4,4919	4,7645	3,0596	0,9728	2,2215	0,37525	1,1701	0,8386	1,5531	0,5216	22,23437958
Relative weight	0,1019	0,202	0,2143	0,1376	0,0438	0,0999	0,01688	0,0526	0,0377	0,0699	0,0235	

Image 51 – ISM Method

7.1.3.1 LYMAN'S NORMALIZATION

Lyman's normalization is important because prioritizing test cases (TCs) using the Independent Scoring Method can lead to inconsistency issues, as the weight of a set of TCs may vary depending on the number of TCs it comprises.

For this reason, we must normalize the coefficients (r_{ij}) in the relationship matrix divide the coefficient obtained through the canonical conversion by the sum of the coefficients in the row of interest. (44)

$$\tilde{r}_{ij} = \frac{r_{ij}}{\sum_{j=1}^{m} r_{ij}}$$

With this ''new coefficient'' we can recalculate the absolute and relative weight.

LYMAN'S NORMALIZATION			A	B	C	D	E	F	G	H	I	J	K	ROW SUM		RELATIVE WEIGHT
Speed	3	12,0%		0,231	0,077	0,231		0,231			0,231			13		11,9%
Live Insights	4	16,0%		0,100	0,300	0,300						0,300		30		16,1%
Accuracy	4	16,0%		0,300	0,300	0,100	0,300							30		15,8%
Usability	2	8,0%	0,290	0,097				0,290		0,290			0,032	31		8,1%
Access Control	3	12,0%					0,083	0,750			0,083	0,083		12		12,1%
Integration	1	4,0%		0,100						0,300	0,300			30		4,0%
Flexibility	2	8,0%	0,231	0,077		0,077				0,077			0,077	13		8,0%
Optimization	1	4,0%					0,474	0,053	0,474					19		4,2%
Tracking	5	20,0%	0,474	0,158	0,474									19		19,8%
Absolute weight			0,1357	0,1403	0,1986	0,0978	0,0773	0,144	0,0197	0,0416	0,0496	0,0584	0,0088	0,971764324		
Relative weight			0,1397	0,1444	0,2044	0,1006	0,0795	0,1482	0,02027	0,0428	0,051	0,06	0,009			

Table 6- Lyman's Normalization

7.1.4 Electre II method applied to QFD

To determine the "winner" among the analyzed vendors, namely the software that best meets the client's needs, the ELECTRE II method was applied to QFD.

ELECTRE is an acronym for Elimination Et Choix Traduisant la RÉalité, which translates to "Elimination and Choice Expressing Reality." It belongs to the category of multicriteria decision-making methods. Using this methodology, a preference relationship, also known as an outranking relationship, is established among the available alternatives. (44)

The method is divided into two parts:

1. Defining the relationships between the available alternatives for each selection criterion.
2. Constructing the outranking table.

The selection criteria analyzed are the most important customer requirements identified in paragraph.

- Tracking ($g_1, w_1 = 20\%$)
- Live Insights ($g_2, w_2 = 16\%$)
- Accuracy ($g_3, w_3 = 16\%$)
- Speed ($g_4, w_4 = 12\%$)
- Access Control ($g_5, w_5 = 12\%$)

The relative weights of each criterion are normalized within the range [0,1] according to the new total.

$$w_{tot} = 0.20 + 0.16 + 0.16 + 0.12 + 0.12 = 0.76$$

The normalized relative importances used in this method are, consequently:

$$w_1 = 0.26; w_2 = 0.21; w_3 = 0.21; w_4 = 0.16; w_5 = 0.16$$

The available alternatives are the software solutions identified for the comparison: Board (c_0); IBM Planning Analytics (c_1); Kepion (c_2); Oracle (c_3) and SAP (c_4).

The relationships between the alternatives, i.e., the preferences for each selection criterion, are based on the QFD benchmarking. Below, the software solutions are ranked according to the score assigned to them in the final phase of the QFD for each selected customer requirement.

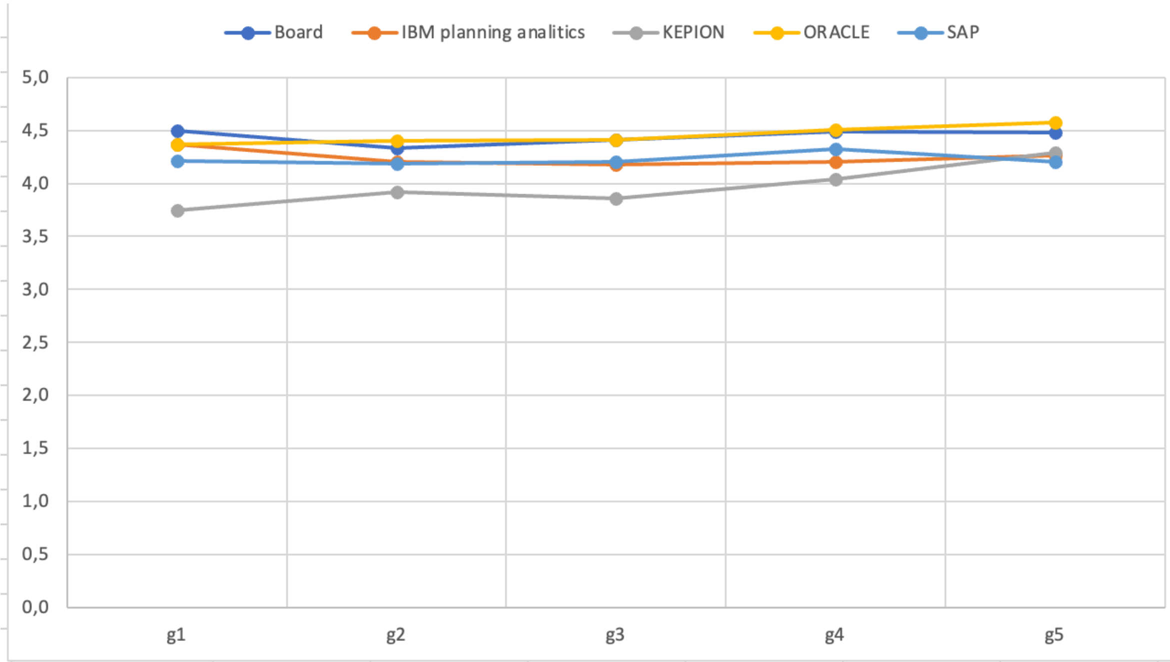

Image 52- Software classification

$$g_1: c_0 > c_3 \approx c_1 > c_4 > c_2$$
$$g_2: c_3 > c_0 > c_1 \approx c_4 > c_2$$
$$g_3: c_0 \approx c_3 > c_4 > c_1 > c_2$$
$$g_4: c_0 \approx c_3 > c_4 > c_1 > c_2$$
$$g_5: c_3 > c_0 > c_1 \approx c_2 > c_4$$

The outranking table, Table 7, compares the alternatives pair by pair and indicates whether one alternative outranks the other. In this case, not all alternatives are compared with each other, but only the pairs involving c_0 to determine whether Board outranks all the others or not.

The structure of the table is as follows (with $k = 0.66$):

(c,c')	$J^+(c,c')$	$J^=(c,c')$	$J^-(c,c')$	$\frac{W^+ + W^=}{W_{tot}} \geq k$	$\frac{W^+}{W^-} \geq 1$	cSc'
(c_0, c_1)	{1,2,3,4,5}	-	-	1,31	∞	si
(c_0, c_2)	{1,2,3,4,5}	-	-	1,31	∞	si
(c_0, c_3)	{1}	{3,4}	{2,5}	0,82	0,43	no
(c_0, c_4)	{1,2,3,4,5,}	-	-	1,31	∞	si

Table 7- Outranking Table

After normalizing the relative importances, $W_{tot} = 0.76$ is considered. In the columns $J^{+}(c,c')$, $J^{=}(c,c')$, and $J^{-}(c,c')$, the cases are represented where, for the i-th requirement, $c_0$is greater than, equal to, or less than c_i, respectively. If both equations are satisfied, then c_0 outranks c_i

From the analysis, it is verified that Board c_0 outranks all its competitors except for Oracle c_3, since for (c_0, c_3), we have: $\frac{W^+}{W^-} = 0{,}43 < 1$

After constructing and analyzing the Quality Function Deployment and comparing the results using the ELECTRE II method, it is concluded that the Board software represents the best alternative available on the market to meet all the client's requirements.

8 Conclusion

The integration of Business Intelligence (BI) into Quality Engineering represents a significant step toward enhancing efficiency and maintaining high standards in business operations. This research explores the crucial role of BI in quality control, highlighting its impact on data-driven decision-making, variability analysis, and the management of non-conformities.

The case study examined in this thesis demonstrates the tangible benefits of adopting BI, including improved process control, more effective reporting, and a proactive approach to quality management. Real-time performance tracking and the ability to respond quickly to variations have led to better resource allocation and reduced operational risks. With BI, companies can transition from a reactive quality control model to a more predictive and preventive approach, minimizing inefficiencies and enhancing customer satisfaction.

This study also emphasizes the importance of implementing BI solutions in real-world business contexts, ensuring they align with company objectives and industry-specific requirements. The findings suggest that leveraging BI in Quality Engineering not only increases operational transparency but also fosters a culture of continuous improvement. Features such as structured data analysis, interactive dashboards, and advanced reporting provide a competitive edge in today's data-driven market.

One key takeaway from this research is the importance of integrating BI solutions with enterprise-wide quality management systems to maximize their impact. It also highlights the need for organizations to embrace a data-driven mindset, where decisions are based on concrete insights rather than intuition. Future studies could explore how artificial intelligence and machine learning enhance BI, pushing the boundaries of predictive quality analytics.

In conclusion, this research underscores the transformative potential of Business Intelligence in quality management. By continuously refining BI-driven quality control strategies, businesses can remain competitive in an increasingly data-centric world. The insights presented here offer a foundation for organizations seeking to strengthen their quality management frameworks through data analytics and performance optimization.

Bibliography

(1) Negash, S. (2004). Business Intelligence. Communications of the Association for Information Systems,13, 177-195. https://doi.org/10.17705/1CAIS.01315

(2) H. P. Luhn, "A Business Intelligence System," in IBM Journal of Research and Development, vol. 2, no. 4, pp. 314-319, Oct. 1958, doi: 10.1147/rd.24.0314.

(3) IBM. (n.d.). Floppy Disk. Retrieved from IBM History - Floppy Disk.

(4) Yasar, K., & Mullins, C. S. (n.d.). Database Management System (DBMS). Mullins Consulting. Retrieved from https://www.geeksforgeeks.org/dbms-architecture-2-level-3-level/

(5) Pascarella, A. (2012). Approfondimento DBMS. Zanichelli. Available at: https://online.universita.zanichelli.it/pascarella/files/2012/09/approfondimento_DBMS.pdf

(6) https://www.bnova.it/business-intelligence/decision-support-system/

(7) Applegate, L. M., Konsynski, B. R., & Nunamaker, J. F. (1986). Model management systems: Design for decision support. Decision Support Systems, 2(1), 81-91. https://www.jstage.jst.go.jp/article/ieejeiss1987/114/3/114_3_286/_pdf/-char/ja

(8) Prof. F:Minelle, materiale didattico del corso “Sistemi Informativi”, Università di Roma 2007 / 2008

(9) Foote, K. D. (2023, April 6). A brief history of business intelligence. DATAVERSITY https://www.dataversity.net/brief-history-business-intelligence/

(10) Azad, M. M., Amin, M. B., & Alauddin, M. (2012). Executive Information System. *IJCSNS International Journal of Computer Science and Network Security*, *12*(5), Shanto Mariam University of Creative Technology, Uttara, Dhaka, Bangladesh.

(11) Business intelligence and analytics: from big data to big impact | Hsinchun Chen, Roger H. L. Chiang, Veda C. Storey | MIS Quarterly Vol. 36 No. 4, pp. 1165-1188/December 2012

(12) Hearst, M. A. (1999). Knowledge discovery from data. Proceedings of the American Association for Artificial Intelligence (AAAI). Retrieved from http://people.ischool.berkeley.edu/~hearst/

(13) Ristoski, P., & Paulheim, H. (2016). Semantic Web in data mining and knowledge discovery: A comprehensive survey. Web Semantics: Science, Services, and Agents on the World Wide Web, 36, 1–22.

(14) Bălăceanu, D. (2007). Components of a business intelligence software solution. Informatica Economică, 2(42), 1-8. TotalSoft.

(15) Mohamed Azmi, Abdeljebar Mansour, Chaimaa Azmi, A Context-Aware Empowering Business with AI: Case of Chatbots in Business Intelligence System, Vol. 224, 479-484

(16) M. Schildhauer, “Data integration: Principles and practice,” in Ecological Informatics: Data Management and Knowledge Discovery: Third Edition, 2017.

(17) Z. Li et al., “Amalur: Data integration meets machine learning,” IEEE Trans. Knowl. Data Eng., 2024.

(18) Aberdeen, “Unified Data Integration: the whole is greater than the sum of its parts,” Waltham, Massachusetts, USA, 2020. [Online]. Available: https://www.opentext.com/file_source/OpenText/en_US/PDF/opent ext-unified-data-integration-in-en.pdf
(19) Foote, K. D. (2024, March 12). *Data integration tools*. DATAVERSITY. Retrieved
(20) Microsoft. (n.d.). *Azure Architecture Center*. Microsoft Learn. Retrieved from
(21) Prof. Elena Baralis, didactical material of “Business Intelligence per Big Data”, Politecnico di Torino, 2024
(22) Khan, R. A., & Quadri, S. M. K. (2012, January.). *Business intelligence: An integrated approach*. The Business School, University of Kashmir.Vol5 number1
(23) Marinela Mircea, (2011), Business Intelligence – Solution for business development, Croatia, Intech
(24) J. Tyrychtr, A. Vasilenko, (2015), Transformation Econometric Model to Multidimensional Databases to Support the Analytical Systems in Agriculture, Department of Information Technologies, Faculty of Economics and Management, Czech University of Life Sciences Prague, Volume VII, number 3
(25) Golfarelli, M., Maio, D., & Rizzi, S. (1998). The dimensional fact model: A conceptual model for data warehouses. *International Journal of Cooperative Information Systems, 7*(2), 215–247. https://doi.org/10.1142/S0218843098000118
(26) https://learn.microsoft.com/it-it/power-bi/guidance/star-schema
(27) Ponniah, Paulraj., Data warehousing fundamentals for IT professionals
(28) Prof. Maurizio Pertichetti, didactical material of “Scienze per l’investigazione e la sicurezza”, Università degli studi di Perugia
(29) Gary Cockins (2013) Enterprise Performance Management Making it Work, EDPACS: The EDP Audit, Control, and Security Newsletter, 48:6, 11-21
(30) Corporate Performance Management (gartner.com)
(31) Langfield-Smith, K. (1997). Management control systems and strategy: A critical review. *Accounting, Organizations and Society, 22*(2), 207–232. https://doi.org/10.1016/S0361-3682(95)00040-2
(32) Limburg, Diana, "THE IMPACT OF ENTERPRISE PERFORMANCE MANAGEMENT ON MANAGEMENT CONTROL" (2010). UK Academy for Information Systems Conference Proceedings 2010. 32. http://aisel.aisnet.org/ukais2010/32
(33) Report aziendali: cosa sono e a cosa servono (mdmtecnodocs.com)
(34) ESTRATTO_024210079.pdf (giuffre.it)
(35) Microsoft Word - 17x Reporting.doc (dronet.org)
(36) KPI - le 9 regole per Key Performance Indicator efficaci (headvisor.it)
(37) Chen, M. (2024, September 23). *What is big data?*)(oracle.com)
(38) Lasi, H. (2013).Industrial intelligence - A business intelligence-based approach to enhance manufacturing engineering in industrial companies.Procedia CIRP, 12, 384–389.
(39) Barney, M. (2002). Motorola's second generation. Six Sigma Forum Magazine, 1(3), 13–16
(40) https://help.board.com
(41) Board Manual : (board.com)
(42) What is the magic Garnet quadrant? (gartner.com)

(43) Magic Quadrant for Financial Planning Software | Regina Crowder, Vaughan Archer, Matthew Mowrey, Michelle Carlsen | 18 November 2024
(44) D.A Maisano, L.Mastrogiacomo didactical material of "Quality Engineering", Politecnico di Torino 2024
(45) Take on Board.Board's 2024 Annual Customer Experience Report
(46) Board Alternative in Financial Planning Software (Gartner.com)
(47) FTE Definition: (Personio)