DeepScience

Business Intelligence with Power BI and Tableau

Cloud-Based Data Warehousing, Predictive Analytics, and Artificial Intelligence-Driven Decision Support

Sibaram Prasad Panda
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Business Intelligence with Power BI and Tableau: Cloud-Based Data Warehousing, Predictive Analytics, and Artificial Intelligence-Driven Decision Support

Sibaram Prasad Panda
Decision Ready Solutions

Anita Padhy
First American Title

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Preface

The Advanced Business Intelligence- Tools and Techniques for Data-Driven Decision Making provides a comprehensive discovery of the modern ecosystem for business intelligence, which detects the development from stable reports to dynamic, real -time analysis A dedicated comparison considers each tool on important dimensions, including matrix prices, integration skills, scalability and purpose, which allows informed decisions. The book concludes by detecting practical, sector -specific applications of BI, showing how industries to reveal insights into health services from finance, to increase efficiency and maintain a competitive management to industries. Whether for IT subjects, data analysts or business executives, this guide acts as a reference and a roadmap to navigate in diverse BI tools.

Sibaram Prasad panda

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Chapter 1: Foundations of Business Intelligence: Fundamentals and Frameworks

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1. The Evolution of BI: From Reports to Real-Time Insights

Organizations have long relied on reporting to evaluate past business operations. Historically, such reporting involved bulky printed sheets containing rows and rows of tabular data, presenting the problem that customers had too much data and too little information. Naturally, this resulted in poor, or no business decisions and any benefits expected from the reports generally proved illusory. Progress in reporting has however not stood still and advancements in computer processing has resulted in a new generation of reporting, real-time reporting. Real-time reporting can be defined as the creation of reports derived from data that is as near to being instantaneously updated as possible. In practice, most reports are generated from data that is uploaded within the last 24 hours.

Real-time reporting presents many advantages to organizations, the first being the ability to react to business needs as they arise; that is, responding to business requirements almost as soon as they surface in the day-to-day operation of the company [1]. Naturally this is contingent on all the relevant business users monitoring these reports on a regular basis. Second, the more regular generation of reports and the employees assisted review of the data is expected to raise the overall standard of data captured, because any frequently occurring data errors or omissions are exposed more quickly and can be rectified timeously. The last benefit may be seen as reactive rather than proactive but having such reports in place can help during moments of crisis by way of increased confidence in the past week's data. However, the introduction of real-time reporting does not come without its pitfalls. Caution must be exercised when implementing real-time reporting.

1.1. Historical Overview of Business Intelligence

Foundations of Business Intelligence Early BI explored static, digitally generated reports to support decision making. Since the introduction of the interactive Dashboard graphical user interface in 1984, BI evolved via On-Line Analytical Processing (OLAP) and interactive multidimensional databases into its current state. BI tools facilitate analysis of historical data (stored in a Data Warehouse) through techniques such as Data Mining and predictive analytics.

Recent market developments have focused on the provision of real-time BI solutions. By combining Relational Online Analytical Processing, enterprise applications and Collaborative BI, Together, these technologies attempt to tackle the traditional limitations of the centralised Data Warehouse in providing decision support for day-to-day operations. The advent of open-source software and Cloud Services as well as the proliferation of mobile devices have further fuelled the illumination on these emerging real-time trends in the market. Today, BI is becoming one of the most strategic and important components of the IT architecture. From the beginning of the BI journey, the major problem organizations had was the lack of an integrated centralized view of data. When the executives assembled their report from different divisions and sources, the numbers simply did not seem to add up. Consequently, the decisions made were not always based on the true business revenue.

1.2. Transition from Static Reports to Interactive Dashboards

Business Intelligence (BI) initiatives have traditionally been run through reporting projects. These projects seek to provide the business with historical information about what happened within the company [1-3]. Typically, reports are always presented as the year-to-date and are nicely sliced with as much filters as anyone can set within the available three dimensions, but still the information is historical. The problem with this type of project, based on reports that are only historical, is that the same analysis can be done manually without requiring a complex project to be established. The BI executives in charge of reporting projects want more; something more operational or strategic and less historical that can give business a visible impact. Those projects that are less historical have a higher appreciation factor by the business, but the investment requires more commitment, more users that can see the value in the project, and more processes and systems connected to BI. The Executive guy is pushing for something Real-Time, or the TPM guys want more Strategic decisions based on the information provided by the reports.

The first shift beyond simple analysis is decision making. This transition seeks to define Key Performance Indicators (KPIs) that help the business examine its health and take appropriate action when some of those indicators show a signal that something is wrong [1-3]. To take this step from viewing many reports to analysing a few indicators that can make a difference, a Dashboard project has to be established. KPIs placed in dashboards offer a clearer display of the information and provide drill-down capabilities that allow business users to understand root causes. Such projects are more operational and require less historical information.

1.3. Real-Time Data Processing and Its Impact

Today's users want their insights in real time. An example can be found in a shipping company that tracks the delivery progress of a shipment. Information about how fast it is traveling—and whether it is still on schedule—is valuable only for a limited amount of time. A delayed shipment, for instance, changes the workload throughout the rest of the journey: It may require a new plan for the route and timing of the cargo ship or plane itself, and a new delivery time slot and schedule for customs clearance. For each of these entities, the original plan was a prediction that was later displaced by real-world events. Real-world events are constantly unfolding and changing the circumstances.

"Today's Business Intelligence users want their insights in real time." This is the challenge that drives real-time data processing—the ability to deliver dynamically updated corporate insights with minimal latency [2,4]. Over the past two decades, the idea of real-time BI has evolved together with the popularity of real-time streaming, operational databases, and data lakes, and its future will be shaped by the maturation of artificial-intelligence technologies. Consequently, many of these emerging BI capabilities have dedicated names of their own, such as streaming BI, embedded BI, AI-enabled BI, and self-service BI. They solve different deployment challenges for different organizational roles, but they share a common goal: to speed up business decision making by providing constant data-access and self-service capabilities for the users.

1.4. Future Trends in Business Intelligence

The Evolution of BI: From Reports to Real-Time Insights Business Intelligence (BI) solutions first appeared as basic reporting applications that generated reports on a weekly or monthly basis. These static reports, which often depended on human interpretation and insight, told a story of what happened the last time the numbers were crunched, but largely ignored what might be happening in real-time—information that could or should influence decisions, policies, or responses. More recently BI solutions have evolved into interactive tools driven by user demand for easier exploration of data. Shaped by current technology trends, BI vendors and organizations are incorporating features such as Ad hoc analysis capabilities, Self-service BI, Real-time processing and visualization, Data storytelling and visualization, Cloud computing, Social BI, Mobile BI, Collaborative BI, and 3-D data visualization [5-8].

The introduction of dashboard interfaces is one of the most visible elements of this transformation. It was the introduction of real-time BI, however, that will change the way the enterprise analyses key performance indicators (KPIs) and corporate dashboards. Understanding the mechanics behind real-time BI is fundamental to appreciating the power and promise of business intelligence today—being able to tell the story about what is happening right now, rather than what happened yesterday [1-2,5-8]. Why is Real-Time BI worth the fuss? And how do we make it work? Exploring the answer requires a more detailed look at the core processes that drive business intelligence today.

Core Concepts: ETL, Data Warehousing, Dashboards, and KPIs The shaping forces listed above focus more on the user experience and the delivery mechanism (dashboards, tablets, and so forth). Core functions, on the other hand, revolve around taking raw data from many different systems in the organization, getting it into one reasonable place, and then converting the data into information—information that can be shared in a consistent manner and at the standard of quality that users demand. It is important, therefore, to revisit the foundational components and technologies that enable Business Intelligence before considering how organizations put BI to work.

2. Core Concepts: ETL, Data Warehousing, Dashboards, and KPIs

Business Intelligence (BI) is concerned with the processes and technologies used to convert raw business data into meaningful and useful information for business analysis purposes. High-level BI activities include gathering direct customer input through surveys or interviews; detailed business information from internal data sources such as Enterprise Resource Planning (ERP) systems; and competitor, industry, and other required information through Forward Intelligence by searching online resources and reviewing consultants' reports and publications. Data sourced from different directory partners can also be included in competitor/industry analysis. The raw data is transformed using Extract, Transform, and Load (ETL) processes into meaningful insights that are then displayed in graphical form on dashboards to enable rapid and insightful decision making. At the top level, Key Performance Indicators (KPIs) clearly indicate the success or failure of the activities, projects, or the overall business; stakeholders are expected to view a daily KPI dashboard.

The term Business Intelligence was introduced in the 19th century, became popular in the late 20th and early 21st centuries with the emergence of computing technologies, and is still evolving [6,9]. BI started with very simple reporting of historical data and analysis using predefined queries. As databases and data and query-processing techniques advanced, intuitive graphical representations of the analysis were introduced. The introduction and development of dashboard-style visualization replaced the traditional presentation of data in textual and tabular form with more meaningful and condensed messages backed up with suitable drill-down features. Today, there is a demand for real-time data loading and real-time BI—in other words, systems that provide immediate information, eliminating the need to filter request-response time.

2.1. Understanding ETL Processes

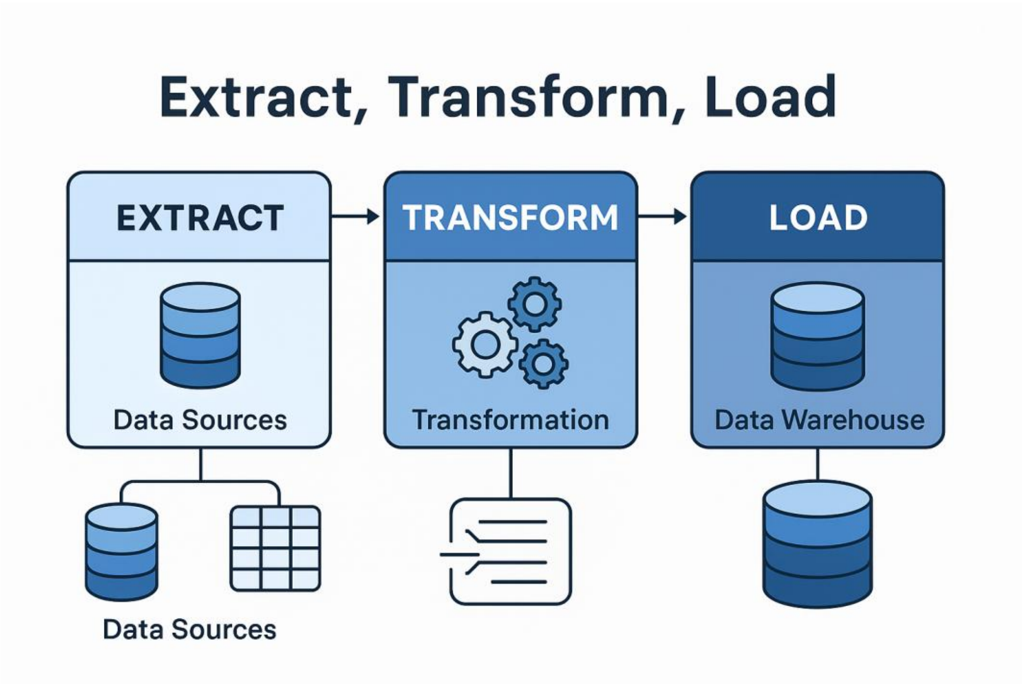
Extract–transform–load (ETL) is a process in database usage and especially in data warehousing. Extract, transform, and load (ETL) refers to three database functions that are combined into one tool to pull data out of one database and place it into another database. In the ETL process, data are extracted from homogeneous or heterogeneous data sources, then transformed for storing it in the proper format or structure for querying and analysis purposes, and loaded into the final target, which is called the data warehouse.

ETL is frequently used in data warehousing. Data is extracted from homogeneous or heterogeneous data sources and is processed for storing it in the proper format or structure for querying and analysis purposes. As of 2009, ETL developments can also be found in EAI tools that support cleaning and matching services during the process of moving data from the source to the hub. Extract–load–transform (ELT) is the process of loading data into the target system and then transforming it there [10].

2.2. Data Warehousing Fundamentals

Data warehouses are a special type of database designed specifically to support the analysis of huge volumes of business data. In the early days of BI, many companies built these databases by extracting business information from operational systems, transforming it into a standard business format, and loading it into the data repository—a process known as Extraction, Transformation, and

Loading (ETL). An ETL process is a core component of almost all BI architectures and is often considered the most difficult to implement.



Figures.1 . Extract–transform–load (ETL)

Business Intelligence systems rely heavily on Data Warehousing as the underlying foundation and starting point. Figures 2.1 to 2.3 illustrate various use cases for BI within an organization. Figure 2.1 depicts the supply chain management scenario, where transaction information is collected from Point of Sale (POS) systems and stored in a data warehouse built for BI analysis. Often, these data warehouses provide a complex Systems, Applications, and Products in Data Processing (SAP) architecture to feed BI requirements. Figure 2.2 shows how the data repository supports BI needs in banking and field services. Figure 2.3 demonstrates Business Activity Reporting needs for small and medium-size businesses. Different companies implement BI based on their interest, requirements, and usage.

2.3. Designing Effective Dashboards

When applied to Business Intelligence (BI), a dashboard provides easy access to Visualizations displaying a company's Key Performance Indicators (KPIs). Effective Performance Management demands a well-designed dashboard that summarizes the KPIs, Highlight Management Exceptions, and supports drilling through the exception to its detailed causes [6,9,10]. However, a challenge is to ensure that users do not overlook KPIs that are outside defined limits but are not actually in an exception state. By showing all KPIs on the dashboard—signalling exceptions for those KPIs that represent serious problems and highlighting those KPIs that are outside the desired range at least ensures that a user is cognizant of all the underlying risks. Dashboards must also be designed to allow rapid drilldown for business users who need to identify the underlying causes of the problem.

Performance Management relies on KPIs that address every key risk and reward area of a business. Ideally, the KPIs should provide an early warning of impending problems as they begin to deviate from the norm in a negative manner. The ensuing drilldown should then help the business easily identify the underlying causes of the issue at hand. Dashboards that apply the principles of Balanced Scorecards enable organizations to monitor their KPIs from a variety of perspectives ranging from Financial to Customer to Internal and Innovation. These groups of KPIs provide early warning signals about potential risks in various business areas. For any area that is off track, a manager can query the dashboard for its detailed KPIs and begin the process of Root Cause Analysis. For instance, if Customer KPIs are pointing toward less customer satisfaction, it may be worthwhile to examine Internal KPIs such as a delay in deliveries or product defects. Root Cause Analysis may further identify causes in the Supply Chain or Manufacturing that explain the delay in deliveries or product defects, which in turn may be traced back to Poor Supplier Performance or an inefficient Manufacturing process. Crucially, the dashboard needs to facilitate such drilldowns quickly.

2.4. Key Performance Indicators (KPIs): Definition and Importance

Key Performance Indicators (KPIs) are quantifiable measures that enable organizations to evaluate their success. Through the presented stages of evolution from business reporting to dashboards, progress is achieved. To track this, KPIs extract essential information from corporate data. However, limited attention is devoted to the process of developing and selecting KPIs. Intelligent organisations analyse KPIs in real-time to quickly identify problems and make timely decisions. Government agencies are increasingly under pressure to deliver valuable products and services within management constraints and imposed guidance. This has highlighted the necessity of measuring performance to assess the achievement of agreed objectives and programmes.

Determining the performance of a city or region requires the selection of indicators located amidst many otherwise irrelevant measurements. Within a government or public sector context, KPIs are selected to direct effort into aspects of public service delivery that are critical to employment and growth, then performance measured using accepted and objective standards [10-12]. These factors enable key decisions to be made by monitoring the measured KPIs. Well-structured KPIs enable agencies and associated delivery organisations to understand their performance in delivering outcomes that are financial, operational, and managerial in nature.

3. BI in the Modern Enterprise: Use Cases and Challenges

Business Intelligence (BI) use is now found in nearly every business function, ranging from product development to sales, marketing, operations and finance. Dashboards and reports play an especially significant role in today’s manager’s day-to-day work. They help cope with a business environment that moves at a dizzying pace. Hundreds, thousands, or even hundreds of thousands of transactions can pass through a company each day. Monitoring for production problems, quality issues, or customer complaints among such volumes of data would be well-nigh impossible without the support of appropriate Key Performance Indicators (KPIs).

During a recent client project, it was striking how many of the business problems mentioned were not particularly new or innovative. Worst-case examples included long-identified pricing errors that continued to reappear; ongoing struggle to manage inventory; cancelled orders that had been shipped and charged; and business processes requiring multiple people and systems to execute what might previously have been done through a manager sitting at their desk [10-12]. While modern products and techniques can certainly reduce the occurrence or impact of problems like these, the fundamental problems themselves have been well known for years. The painstaking execution of BI is not easy. Regardless of the progress made towards providing real-time information, construction system and infrastructure remains the achievement of many enterprises.

3.1. Case Studies of Successful BI Implementations

Consider a media company that acquires websites. The corporate strategy is to invest capital and resources in growing the number of users on each platform, thereby increasing revenue and capitalizing on economies of scale. The company has a budget of $500,000 and must decide whether to invest funds in building or acquiring content or in centralized SEO resources.

A traditional BI approach might involve generating a report that staples together several charts, graphs, and tables based on historical data. A report of this nature could be a starting point for the investigation, but it is relatively high-level and, as noted earlier, more tactical and exploratory in nature than strategically prescriptive. The analysis would slow down the decision-making process and could be easily challenged or disproved by even slightly different or more detailed parameters. A more tactical approach would be to build a centralized SEO system that would allow each individual website to see keywords that are ripe for growth, how much traffic would be generated if they ranked for those keywords, and the difficulty of ranking for those keywords. Additionally, such a system could provide the ability to group keywords around topics to assist with the creation of more comprehensive and topical content. "The Evolution of BI: From Reports to Real-Time Insights" outlines the underlying technology and knowledge that has enabled the evolution of BI.

3.2. Common Challenges in BI Adoption

A key part of successful BI deployment is assessing critical success factors. It may seem obvious to say that most organizations want to leverage their vast data to resolve questions and support business decision-making; however, many BI rollouts fail to meet expectations because these fundamental relationships are not sufficiently emphasized. Common challenges in BI adoption include avoiding data silos, creating demand for BI results among business users, adapting organizational decision-making procedures to incorporate BI-detected opportunities or threats, and setting up BI for growth beyond immediate deliveries as business and data volumes increase. BI systems, although sophisticated, do not operate in isolation from business processes. If organizational tensions arise because business executives feel undermined or decisions are made automatically based on BI output, it can lead to inflexible pre-commitments that later business process interventions find hard to invalidate. Allowing adequate time for organizational changes to leverage continuous and changing BI results is equally important to providing a suitably scalable platform. When implemented properly, BI can identify key performance areas and opportunities for improvement that, when acted upon, result in improved financial and operational performance for the business.

3.3. Overcoming Data Silos in Organizations

Corporate information is often distributed globally throughout the business and its various data centres and networks. Many of these facilities may have a wide range of information storage media for data, ranging from modern electronic databases to much older mechanical or paper operating files, files of contracts, and such critical documents as decrees issued by the company. Organizations, especially those with many employees, produce a great deal of information about their operational activities. Unfortunately, neither internal data silos created by departments and functions nor external data silos created by customers and suppliers have yet been eliminated [7,13-16]. These data silos, therefore, continue to encumber the efficient use of Business Intelligence techniques. During BI implementations, therefore, management is often faced with the problem of data consolidation from heterogeneous sources within various parts of the corporate information infrastructure during the immediate process of Data Warehousing Design.

3.4. The Role of AI and Machine Learning in BI

The advent of artificial intelligence (AI) and machine learning is also reshaping the use of business intelligence. Organizations are pairing BI tools with AI and machine learning algorithms to automate data collection and analysis, thereby accelerating decision-making. This integration enables a shift from retrospective to prospective business intelligence, where predictive and prescriptive insights support forward-looking decisions.

Real-time decision-making remains paramount. Flash, the originator of visual dashboards, powered Goldman Sachs' RiskEye dashboard, which offers a panoramic view of market risk positions for all traders at any time. As the technology evolved, Hewlett-Packard transformed the RiskEye dashboard into an intelligence dashboard that combines risk positions with current accounting data, enabling traders to make informed decisions about new trades in real time. The evolution thus progressed from reports to dashboards and then to dynamic, real-time decision support.

4. The Role of Data Governance in BI

Business intelligence is primarily used to describe the processes and technologies used to translate raw data into information that decision makers can then use to support operational decisions and strategic initiatives. However, because different businesses have different goals and business challenges, the implementations of business intelligence—and therefore the definition—vary. Analysts typically categorize BI tools and systems according to the business process each supports, including, but not limited to, financial performance management, budgeting and forecasting, and supply chain optimization. BI technologies also are classified according to their analytic capability, including querying, reporting, Online Analytical Processing (OLAP), statistical analysis, forecasting, and data mining. BI is delivered through dashboards, scorecards, reports, and alerts, which compare analyses with pre-established Key Performance Indicators (KPIs) or thresholds [2,17-19]. The integration of financial and operational information enables companies to analyse product and customer profitability, allocate expenses, evaluate the effectiveness of promotions, execute pricing decisions, assess capital projects, and understand which customers are most profitable. Consolidation of financial statements and visualization of key performance indicators—including realized sales, cash flow, inventory turnover, debtor days, and customer profitability—gives management access to current financial performance.

The Evolution of BI describes how business intelligence has progressed over the past two decades, highlighting important turning points and suggesting how the business intelligence landscape may continue to evolve heading into the future. Core Concepts explores data integration, data warehousing, dashboards, and Key Performance Indicators (KPIs), revealing the processing of information that supports modern decision-making. The Use Cases examine practical applications of business intelligence and the resulting improvements in decision-making, while The Challenges identifies several challenges typically encountered with these initiatives.

Across all these topics it becomes clear that business intelligence continues to move towards real-time insight. The Role of Data Governance discusses the data quality and regulatory compliance initiatives that must be incorporated to ensure reliable and sustainable outcomes, and Emerging Technologies analyses the impact of cloud computing and Big Data on business intelligence. The potential of predictive analytics and self-service BI initiatives is examined, and the Future of BI section highlights strategic initiatives that are shaping the future directions of business intelligence.

4.1. Importance of Data Quality

Data quality has always been one of the most important considerations for business intelligence, as the analyses and reports are only as good as the data fed into them. Business Intelligence showcases facts and figures to support decision making, and therefore those supporting figures need to be accurate, valid, timely, complete, consistent, and unique. Recent years have seen an increasing emphasis on data governance.

Businesses need to submit financial results and tax calculations to government departments by a certain deadline. Government departments need Home Office statistics on population for policy making [3,20-23]. Both the businesses and the government departments need to ensure that data is submitted on time and the figures are accurate and valid. Quality and integrity in these reports and analyses are therefore paramount. Data quality frameworks encompass all the policies, procedures, and processes that ensure the accuracy of the data supplied to government departments.

4.2. Regulatory Compliance and BI

The Role of Data Governance in BI, with an emphasis on Regulatory Compliance Data governance—including data quality management and regulatory compliance—establishes the framework within which organizations exploit information as a resource in competitive and tactical decision making. As organizations are increasing their reliance on BI and BI applications, responsibility for regulatory compliance—particularly Sarbanes-Oxley, Basel II, and the Health Insurance Portability and Accountability Act (HIPAA)—is being top of mind for executive management. Regulatory compliance requires that organizations be able to demonstrate the following: - Financial reporting accuracy and integrity - Data security and access - External data-file integrity - Information confidentiality - Auditability and transparency - Timely reporting (e.g., monthly, quarterly, and annually)

Organizations must therefore have a data governance program in place that also ensures the accuracy, consistency, availability, and integrity of the required data for decision making, including support for Sarbanes-Oxley, Basel II, and HIPAA compliance. Within Enabling BI, the term data governance sometimes refers specific to regulatory compliance. In this context, data governance requires that the data management function demonstrate the following: - Data accuracy and consistency - Security and access - File integrity - Confidentiality - Auditability and transparency - Audit statement and its components - Timely reporting (e.g., monthly, quarterly, and annually)

4.3. Establishing Data Governance Frameworks

Data governance focuses BI on the quality and shape of data. A corporation may use business intelligence tools to ensure compliance with legal and regulatory requirements. Incorrect taxation reports, broken SOX regulations, and improper forecasting for the corporation are likely to be caused by a lack of data quality. Many large corporations establish a data governance office that sets standards and policies designed to ensure high-quality data [9,24-26]. Over time, data governance reveals the corporation's commitment to producing believable data.

Business intelligence requires a robust data governance framework to provide a standardized practice that establishes clarity on who has data access and what can be done with the data. The BI data governance framework specifies who can alter or change the data. The framework also specifies the range of activities allowable with the data. This becomes especially important when there is more than one BI tool available to users in the organization to perform analysis or generate reports. Establishing a data governance framework is a critical step in achieving BI goals and objectives.

5. Emerging Technologies in Business Intelligence

Cloud computing has had a significant impact on BI by providing virtually unlimited self-service access to computing resources that can be obtained and paid for on demand. These developments have changed the nature of BI from a fully managed, on-premises, persistent database to a distributed and flexible analytical environment. The promise has always been that the new environment will make BI for the masses a reality—less expensive and more scalable and accessible. Yet despite these advantages, many corporations remain reluctant to migrate their enterprise BI environments to a public cloud.

Big data projects also usually implement some sort of hindsight…insight…foresight business analytics whose levels of sophistication and complexity vary widely from company to company, depending on the nature of the specific challenge or opportunity being addressed. Mobile BI, which historically has been an extension or afterthought of BI, is growing rapidly [27-29]. Smartphone and tablet users are much more demanding and expect easy access to reports and dashboards that are custom configured for their small screens. Unfortunately, delivering high-quality mobile BI content has proven to be more difficult than vendors anticipated.

5.1. Cloud Computing and BI

Cloud computing architectures provide shared data center resources as services via the public Internet. Examples include Amazon Web Services (AWS), Microsoft Azure, and Google Cloud Platform. Cloud offerings deliver elastic compute capabilities, storage space, and network capacity, enabling organizations to rapidly scale resources according to demand. Key features of cloud offerings include "pay as you go" pricing models, scalable resources, and elasticity of service.

Cloud services for business intelligence are also hosted in the cloud on a third-party's cloud platform and delivered on demand to users anytime and anywhere via just a browser. Big data itself is often stored in the cloud using public cloud resources and platforms such as AWS, Azure, and Google Cloud. For example, leading analytics service providers have designed and implemented elearning modules and customer support services for their big data and cloud offerings, making use of specialized toolsets [30-32]. Equally important is the growing use of cloud-based Business Intelligence, Analytics, and Big Data IT paradigms.

5.2. Big Data Analytics in Business Intelligence

Business intelligence allows a company to go one step further in the information discovery cycle: enabling users without technical training to interact with the data and receive answers to business-related questions. Ideally a user can specify what information is desired in a form that is as natural and pertinent to the business as possible, which is usually a data visualization. The role of Big Data analytics in Business Intelligence has been particularly emphasized. Analysis performed on Big Data allows businesses to realize their future potential through Product innovation, process enhancement, market and business development. Hence it is rightly said, "Insights from large volumes of data, labelled as Big Data today, promise to become the corporate precious gems of future."

The existences of data silos form one of the important reasons for failure or partial success of BI solutions in many organizations. Most organizations are already struggling to incorporate enterprise-wide data and information in an integrated manner to support a better BI environment. The next wave in the field of business intelligence adopts the concept of Service-oriented architecture, which enables interaction with different services existing in an organization. These services encapsulate the underlying data, information and functionality. In the Service-oriented Business Intelligence framework, all business processes and workflow data of an enterprise can be accessed by Business Intelligence tools at any time and from anywhere.

5.3. Mobile BI: Trends and Applications

Business intelligence dashboards offer a high-level view on key performance indicators (KPIs) that matter to a business at any moment in-time. When properly developed, BI dashboards give executives the ability to understand the performance of their business and to make better decisions moving forward. The intention is to develop the dashboards in such a way that decision-makers can engage in ‘what-if’ planning and forecasting and act based on facts rather than gut feel.

Besides conventional desktop or laptop access, the ability to consume and interact with BI dashboards on a mobile device can be a real differentiator for the business. With the power of mobile BI, executives can stay on top of their business at any time, from any location—whether customer, supplier, or site visits–thereby shortening the response cycle. It is considered best practice to design BI dashboards to fit the specific needs of mobile business users. Understandably, the mobile BI screen plays a huge role in user adoption and should be well thought through to ensure a positive user experience.

6. The Future of Business Intelligence

Predictive analytics represents a forward step from today's extensive use of dashboards and key performance indicators (KPIs). Business Intelligence (BI) tools have been built on appropriate databases that store current and historical data in a clean, consistent, integrated manner capable of supporting analysis. Predictive analytics seeks to understand trends and provide foresight into what may happen. Self-service BI enables business users to independently access a wide range of information without relying on a technology team to gather and present the information [9,33-35]. The integration of Enterprise Resource Planning (ERP) and Customer Relationship Management (CRM) information with other functions such as finance and procurement will also drive future BI initiatives.

Dashboards, Key Performance Indicators, and Trends. Business Intelligence presents performance information in a summarized format using dashboards that incorporate graphical gauges, charts, and tables. These customer-facing dashboards can be used during a complaint call or to track visit schedules. MI (Management Information) is not merely physical information but also performance information. The underlying BI technology creates the opportunities for implementing such frameworks [36-38].

6.1. Predictive Analytics and Its Implications

Predictive analytics deals with methods that make forecastings about future behaviour of data. With predictive analytics, historical data is fed into analytic models, which are then run through instances of production or what-if scenarios. The results help recognize interesting patterns, predict future data behaviour with improved accuracy and suggest actions based on predictions. All these support decisions making and proactive action, thus creating a significant impact on operational and financial bottom lines.

Predictive analytics is applicable in many different industries, including telecommunications, financial services, manufacturing, retail, and so on. More business scenarios and associated processes are being analysed and modelled to exploit predictive analytics capabilities [36-38]. Moving beyond reporting and optimisation, this area signals the real value creation potential within Business Intelligence and its merger with other areas of the enterprise such as Business Process Management and enterprise Risk Management. The notion of CI supports the real-time enterprise and the holistic concept of sense-and-respond enterprise where the agility of business is increased in terms of its operational performance and its ability to react to customers in real time.

6.2. The Shift Towards Self-Service BI

Self-service BI is centered around one fundamental problem: decision support capabilities are scarce and the demand to facilitate sound decision making is huge. In many companies, only a few people have the resources to analyse data and extract answers from it. The likes of journalists, accountants, marketing analysts, BI consultants, market researchers, database administrators, and data scientists can use reporting and analytics tools, structured data, and resources to answer some of the strategic questions they face. Demand, however, far exceeds this supply. Hence, the BI department inevitably becomes a bottleneck for answering questions that could otherwise mature the business. Besides the sheer volume of requests, it is also the diversity of questions and need for rapid delivery that limits the range of queries that can realistically be supported. The World Economic Forum1 has ranked general data analytics knowledge as the most sought-after skill in today’s job market. Self-service BI, in its simplest form, provides all employees with the tools they need to generate their questions directly, in near real-time. Information technology can become the company’s secret weapon in this battle. Enabling a self-service BI environment is of utmost importance for kindness, concern, and care for the rest of the company. It can supply the tools needed to manage changes in the market with the rapid responses the market demands.

Self-service BI levels the playing field, making key data and analytics available to anyone who needs it and empowering them to perform their own searches and analysis of the data. It takes the DRY principle—"don’t repeat yourself"—to the next level and makes it possible for the company to scale and evolve by removing the bottleneck that is knowledge and data in the BI department. Offering the right tools to the people in the field grants them the autonomy and power they need to perform tactical and operational business manoeuvres when called for, and to explore new paths to growth and profitability beyond that.

6.3. The Integration of BI with Other Business Functions

Business Intelligence (BI) tools enable managers and employees to analyse historical data and make informed decisions. Strategic business functions such as marketing, manufacturing, and finance depend on BI systems and data to improve decision-making processes. The integration of BI with other business functions enhances collaboration, fosters information sharing, and drives more cohesive decision making. By incorporating BI into the daily activities of various business units, companies can adapt more quickly to marketplace changes and identify unmet customer needs. The growing importance of collaboration and knowledge sharing also extends to suppliers and customers. Integrating BI with functions such as Supplier and Customer Relationship Management (SCRM) results in greater business visibility, improved communication among stakeholders, and increased competitive advantage.

Although the adoption of BI applications continues to grow, the utility of BI data is still underexploited. The economic and business impact of BI applications information remains largely negligible in many organizations, with data often treated as a byproduct of business activity rather than as a primary resource. Additionally, in most organizations, transactional applications of ERP, SCM, and CRM are areas of strength compared to the analysis offered by their business intelligence counterparts, SAP-BW and Business Objects [3,39-40]. Making the BI function more operative and pervasive is now a significant challenge for organizations. Exploring the potential role of BI in mid-sized companies offers new insights into the effects of BI and the changes that BI organizations must undergo to shift from a self-service to a business intelligence as a service orientation.

7. Conclusion

Business Intelligence (BI) tools and techniques have long been used by enterprises to facilitate competitive and efficient decisions. The potential benefits from using BI are tremendous. BI tools enable access to the right information at the right time to make better strategic, tactical, and operational decisions and enhance business performance. For example, a warehouse manager can track inventory levels and monitor purchase and sale transactions in real time. Connectivity to sources such as bar code scanners and point-of-sale systems enables such real-time insight.

Several organisations’ success stories attest to the power of Business Intelligence and Enterprise Resource Planning: Companies such as Amazon, Dell, Hershey’s, Wal Mart, and UPS use Enterprise Resource Planning software on a highly customized basis. Successful Enterprise Resource Planning implementations utilise “best practice” processes built into the software. For instance, General Electric (GE) saved $300 million in inventory costs in one year by making the Enterprise Resource Planning system the source for all inventory data. The Toyota suppliers’ collaboration system enables Toyota and its suppliers to share demand, order, inventory, and production data, which helped Toyota reduce inventory costs while maintaining superior company performance. As a final example, the company used Business Intelligence tools to respond more effectively to customer service inquiries.

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Chapter 2: Power BI Deep Dive: Microsoft's Business Intelligence Ecosystem

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1. Introduction to Business Intelligence

Business Intelligence refers to the processes, technologies, skills, and applications used to transform data into knowledge. The role of Business Intelligence is to support better business decision making through the analysis of past, present, and future business operations and conditions.

Fundamental concepts of Business Intelligence can be visualised as technical architecture. Microsoft Power BI is a suite of Business Intelligence tools that enable data analysis and sharing of insights through rich visualisations. It is capable of accessing data stored both on the Microsoft Azure Cloud and on-Premises in a Microsoft SQL Server database, making Power BI an ecosystem rather than a standalone product. Power BI can also consume data from a variety of other Azure Cloud services, such as Azure Data Lake, Azure Data Storage, Azure HDInsight, Azure Synapse Analytics, and Azure Analysis Services [1-2].

2. Overview of Microsoft Power BI

Business Intelligence (BI) is a set of tools and techniques that helps businesses make better decisions through data analysis. It also provides businesses with measurable information that they can use to measure productivity. Besides, it can help businesses to forecast and predict possible sales for the coming months based on historical data. It is a full ecosystem that accomplishes data ingestion, preparation, transformation, visualization, and analysis. Microsoft Power BI is one of the best self-service business intelligence tools, supporting data-driven decision-making in an organization.

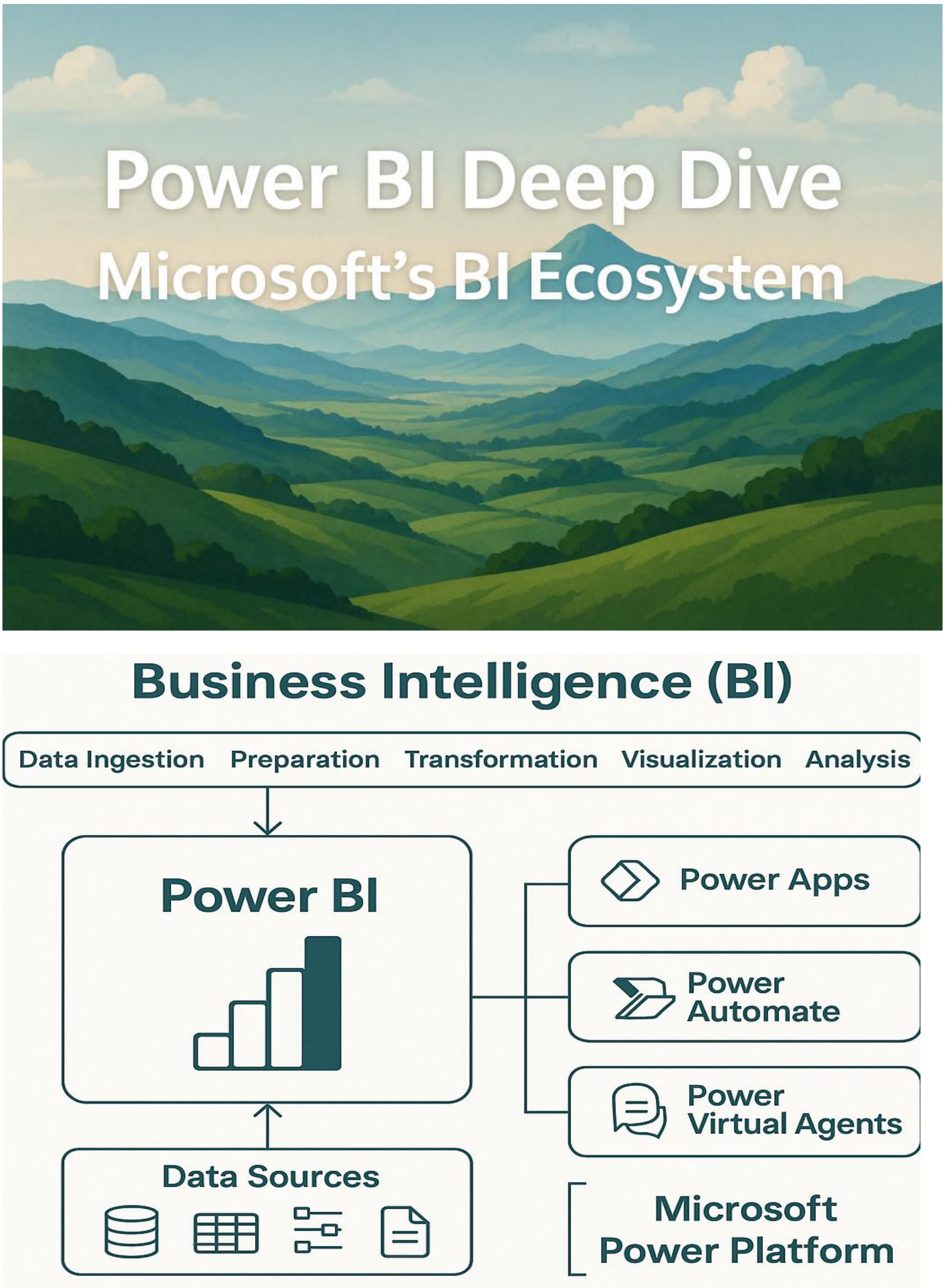

Fig 1.BI architecture

The landscape of Business Intelligence is vast and diverse, with an increasing number of technologies available for various requirements. Although the initial phase of BI projects was time consuming and required IT involvement, manufactured tools like Power BI have transformed the field. Power BI stands out due to its extensive range of useful features and its status as a part of the Microsoft Power Platform, a comprehensive and scalable ecosystem for business applications. The Power Platform enables organizations to build end-to-end business solutions with low-code technology.

3. Power BI Architecture

A proper understanding of business intelligence can be achieved only through a comprehensive study of Power BI, a business intelligence tool. Diving deep into Power BI features requires a solid foundation in business intelligence concepts. Business intelligence encompasses processes, architectures, and technologies that transform raw data into meaningful and useful information for business analysis [2]. Power BI enables users to access, explore, analyse, transform, visualize, disseminate, and generate reports. It offers interactive visualizations and self-service business intelligence capabilities, empowering business users without requiring extensive data analysis or reporting skills.

The Power BI architecture constitutes an ecosystem of diverse tools and services designed for data transformation, visualization, sharing, and exploration. These tools and components enable users to create compelling data visualization reports that enhance decision-making. Integrating all these services into a single cloud platform establishes a scalable, cohesive enterprise business intelligence solution accessible via Web, desktop, and mobile. The architecture includes Data Sources, Data Modelling, the Visualization Layer, and Data Refresh and Storage. Data Sources refer to the origins of external data, which are organized into tables within Power BI. Data Modelling involves structuring and organizing the data to create a data model that facilitates meaningful insights across tables. The Visualization Layer presents the structured data in various chart formats for easy understanding. Data Refresh and Storage encompass the mechanisms for storing population-specific data and updating Power BI reports with the latest data.

3.1. Data Sources

1. Introduction to Business Intelligence Business intelligence (BI) is a process for delivering information and insight to decision makers. Organizations use business intelligence to support operational or strategic decisions, and to optimize

business processes. Business intelligence uses data related to the organization and its business environment, such as financial, operational, and competitor information. As organizations carry out their day-to-day operations, they generate substantial amounts of data, regardless of industry or size. Data analysis methods can range from standard business reports to complex analytical operations that identify trends and predict outcomes based on historical data. Organizations strive to learn from data history to make better decisions and optimize operations.

Power BI is Microsoft's direct response to the development of technologies that facilitate data exploration, visualization, and generation of valuable insights in a user-friendly manner. Regardless of language, education, or cultural background, all people are receptive to visual content; Power BI creates companies' reports and dashboards, making data universally accessible and understandable.

2. Power BI Architecture Many companies use multiple systems for generating reports and business dashboards. For example, ticket cost reports during a flight are generated in ticketing systems, while airport arrival and departure times are obtained by connecting to the SITA system. Power BI permits a connection to different sources and caters to the requirements of the report/dashboards users by consolidating data sources as the final output.

The architecture of Power BI involves several components. Data Sources represent diverse databases or files in folders. Data Modelling involves the transformation of source data and the use of Business Intelligence calculations through the DAX language [2-4]. The Visualization Layer displays the objects from the Model and includes charts, tables, cards, scatter plots, and gauges. Finally, Data Refresh and Storage assure the updating, scheduling, integration, and security of the reports and dashboards. Practical applications of these concepts are developed in the Power BI Desktop, Power BI Service, and Power BI Mobile subsections.

3.2. Data Modelling

Business Intelligence (BI) is a set of technologies and processes that organizations use to collect, analyse, and present business data in a meaningful way to enable easier and better decision-making process. It allows companies to turn raw data into understandable information. For example, understanding the demographic characteristics of customers can allow a company to develop targeted marketing campaigns. A Financial Data Analytics Report that displays monthly and annual revenue, profit, and costs helps in formulating strategic goals.

Microsoft Power BI is a collection of several Software as a Service (SaaS), desktop applications, and connector services that enable business users to visualize their data on a consolidated platform. It allows users to transform data from disparate sources into interactive, easy-to-consume, and de-tangled reports and dashboards. Power BI's capabilities include data modelling, data visualization, data sharing, report publishing, and others. These functions can be performed using Power BI tools in conjunction with Excel, Azure-cloud platform, SQL Server Analysis Server, and an on-premises Power BI Report Server. The Power BI architecture can be described in four sections: data sources, data modelling Layer, visualization layer, and report storage/refresh. The Architecture section of Power BI details the data sources that can be connected to Power BI. The Power Query section explains the creation of Business Intelligence reports that provide dimensional or relational visibility for the Tabular model. The Data Analysis Expressions (DAX) section details the creation of calculated columns and measures for easy data analysis. These elements of the Architecture section, in combination with Power Query and DAX, enable the creation of advanced Power BI reports.

3.3. Visualization Layer

Microsoft Power BI is a data visualization tool that enables the display of data through visual reports in the browser. Users can create charts, graphs, and other visual artifacts. The software's graphical front end responds to queries against the underlying data model, executed in the in-memory Analysis Services engine. Datasets and reports can be published directly to the Power BI Service and the Power BI Mobile application.

Power BI supports a range of data sources, from the simplest Excel worksheets to complex datasets, such as those from a cloud service, on-premises database, or big data source like Azure Data Lake Store. It has built-in connectors for Google Analytics, QuickBooks, and Salesforce, among others. An additional software component called Power Query enables data manipulation within the ETL process of Power BI [5-6]. ETL consists of gathering data from different sources into a staging area (the Query tab in Power BI). Once the last transformation is made, data is pushed into Power BI's data model using DAX once the CSV is loaded.

3.4. Data Refresh and Storage

The Data Refresh and Storage components determine how data is managed and maintained. Power BI connects with multiple data sources, permitting refresh operations that update the dataset in Power BI whenever changes occur. Scheduled refreshes can be configured to run automatically or triggered by user requests. Power BI is compatible with Source Control Systems such as GitHub and Azure DevOps, which enhances collaborative project development. Different Data Refresh options can have varying processing schedules, with Premium and Embedded Capacities enabling more frequent updating than Pro Capacities. Data storage options such as Import Mode, Direct Query Mode, Aggregation, and Hybrid Models determine how the data is cached and utilized. Import Mode caches the data through scheduled refresh; Direct Query Mode queries the data source directly without caching, although this can impact Performance. Aggregation in Direct Query Mode takes advantage of pre-cached data at aggregated levels; Hybrid Models combine Import Mode and Direct Query Mode, tailoring data access and performance to analytical needs.

4. Power BI Desktop

Power BI Desktop is the launchpad for building stunning, effective reports and dashboards. It's a free Windows application from Microsoft that makes it easy to create reports leveraging Power BI's AI capabilities. It also provides a flexible canvas combined with more than 85 modern data visuals from Microsoft and the community to design tailored reports and offers a broad set of shaping, modelling, and authoring features for the data within. Power BI Desktop serves as a sophisticated report authoring environment, enabling the creation of data models and the definition of measures using DAX. When these reports are published to the Power BI service, they become dashboards and datasets for your users.

Setting up Power BI Desktop is straightforward, with the application readily available for download from the Power BI website or the Microsoft Store. The user interface is intuitively divided into four main areas, facilitating navigation and report creation. These areas encompass the side ribbon (including Fields, Visualizations, and Filters panes), the main ribbon at the top, the report-building canvas, and the page navigator at the bottom. Crafting a report begins with loading data from a chosen source on the Home Ribbon—after which the report is ready for building and beautification.

4.1. Installation and Setup

Power BI Desktop represents the foundational client-side component of Power BI, a comprehensive business intelligence solution engineered by Microsoft. Offered free of charge, the application can be acquired via the Microsoft Store or by downloading the executable installer package. Additionally, Power BI Report

Server, allied with Power BI Premium, facilitates on-premises report hosting and offers a specialized version of Power BI Desktop.

Facilitating an interactive approach to report design, the tool accommodates a spectrum of use cases from advanced corporate scenarios to basic reporting requirements [7,8]. An intuitive functionality, encapsulated in a single button, simplifies the triggering of logical, incremental report refreshes, enhancing user efficiency. With stand-alone complexity and a user interface dedicated to report and dashboard assembly, Power BI Desktop receives the full and constant attention of its design team, ensuring consistent evolution and responsiveness to the needs of the power user community.

4.2. User Interface Overview

Within Power BI Desktop, the Field List, Visualizations pane, Report View, and Page Settings pane are all encompassed in one section. While this offers convenience, the layout is overwhelming at first glance. By advancing through the tutorial, the user gains an appreciation for the seamless completeness of this all-in-one solution.

The Power Query and Data panes are displayed separately, aligned alongside the Fields section of the Field List in Report View. The dual approach is eloquent in concept and becomes immensely valuable in practice.

4.3. Creating Reports

The Visualization pane enables users to easily add visualizations by simply dragging and dropping them onto the interface. Each visualization is highly customizable, allowing you to add numerous fields and utilize features such as drill-down and detail hierarchies. Tooltips can be configured for each visualization to display additional, user-defined information when the cursor hovers over specific elements. Practical examples can be explored within the Visualization pane setting.

The Fields pane lets you add columns and tables from the data source to the visualization. Numerical values can be used for aggregation calculations like Sum or Count, while categorical values serve as categories, legends, or thresholds. The Filters pane offers a convenient way to add report-wide or visual-specific filter conditions, effectively managing the visibility of data in the report. Multiple pages facilitate the inclusion of different view types within a single report.

5. Power BI Service

Power BI Service is still evolving. It enables you to publish Power BI Desktop reports, assign scheduled refreshes, and set row-level and object-level security; the Power BI Service is built on the Microsoft Azure cloud platform.

Power BI Service simplifies report sharing and embedment with no requirement to create an external secure environment. Many productivity tools are added frequently. Power BI Service also enables users to connect directly to a published Power BI Desktop report and analyse the report data in Excel through a live connection.

5.1. Publishing Reports

Business Intelligence (BI) involves the technologies, systems, practices, and applications that analyse an organization's raw data in detail and present actionable information that helps executives, managers, and workers make better business decisions. Microsoft Power BI is a Business Intelligence tool that offers interactive visualization [9-12]. It uses a user-friendly interface, simple query language, and drag-and-drop features to create custom reports and dashboards.

Power BI's Architecture enables the integration of multi-source data to create comprehensive reports, which can be published and shared across the enterprise. After creating the Data Model, the visualization layer builds cohesive and interactive reports. The reports are then published to the Power BI Service–a cloud SaaS–to share the reports with decision-makers, making them accessible anytime and from any device. The reports are connected to abstraction layers through which the data is created, and a report refresh mechanism ensures the views reflect the most recent updates.

5.2. Collaboration Features

A key benefit of Power BI Service is publishing reports to share with users of differing skill levels. The report can be shared remotely, if required, with users that can either interact with it in Reading mode or be allotted editing rights.Also, Power BI Service allows the creation of Workspaces to hold content such as reports, dashboards, datasets, and workbooks. Users can be added to each Workspace with very specific access rights—Admin, Member, Contributor, or Viewer. It is recommended to use Workspaces for managing content instead of individual reports as this is much easier to maintain at scale. However, this feature is only available to users with a Power BI Premium license, with a free license only allowing the creation of content in the one personal Workspace that is provided.

Finally, Power BI Service supplies a wide variety of schedulable alerts, enabling users to be notified when specific values in their reports satisfy some triggering condition (such as exceeding a defined limit). These alerts can be created with minute-level granularity and distributed to any number of users via e-mail or via Microsoft Teams. Detailed guidance on licensing requirements and creation of each of these features is provided in the Microsoft Power BI documentation.

5.3. Data Sharing and Security

Business users typically consume reports created by Power BI Desktop via Power BI Service and Power BI Mobile. All those reports, in fact, use the database and data visualization services. Data visualization services allow users to share Power BI reports with their colleagues and business partners through a process that utilizes workspaces and applications. When a report is ready to be shared, it can be linked to a workspace and then published as an app. Access to the app is granted by inviting users or security groups through Microsoft 365 integration. Proper configuration of Azure Active Directory security groups pertaining to security roles of a report in the Power BI Service ensures that users see only reports, dashboards, and apps from workspaces to which they have access.

Apart from report sharing, the Power BI Service also supports data sharing. Analysis Services live connections are a typical case in which the Power BI Service is used as a platform that enables users to perform data analysis in any device, without sharing their credentials, while the data modelling is performed on-premises and data is never exposed outside the local network.

6. Power BI Mobile

Org_App_Mobile_BI_Best_Practices.md explains how the Microsoft Power BI mobile app supports on-the-move decision making by enabling users to access and ask questions of their Power BI reports and KPIs from their Android and iOS phones. To create a compelling mobile report, optimization of the desktop report layout is necessary to achieve the best user experience. The mobile app can be downloaded from Google Play for Android Devices or Apple Store for iOS Devices.

Microsoft Power BI Mobile Services allow users to access reports and business insights on any device through a mobile app for Windows, iOS, and Android phones and tablets. The interactive mobile reports give users the ability to keep up-to-date by providing alerts to their phone or tablet. Mobile reports allow users to be connected, engaged, and informed with their business data wherever they are.

6.1. Mobile App Features

The Power BI mobile app significantly increases business intelligence accessibility and usability by enabling users to interact with business data on the go [7,13-15]. Reflecting Power BI's comprehensive approach, the mobile application offers a rich set of features: the option to choose in-app settings, share ideas or feedback, customize the mobile experience for personal success, and stay updated with enhancements. Users can easily connect to the support team, rate the app, create a shortcut on the home screen, and get help.

The app's menus enhance user interaction—"About the app" provides information on features, company blogs, and legal licenses; "Subscribe for updates" allows users to receive notifications on new features, tips, training sessions, webinars, and Power BI-related events. Under "Help improve Power BI," users can review the experience, submit ideas or requests, share screenshots, and access the Power BI Community. The mobile workspace includes browsing with a home-screen shortcut and support options for assistance and rating.

6.2. Optimizing Reports for Mobile

Modern businesses require access to critical data anywhere and at any time. The Microsoft Power BI mobile app caters to this demand by enabling users to view dashboard and report data on iOS and Android devices. Most report elements—including visuals, slicers, cross-filtering interactions, and drill-down functionalities—are accessible via the mobile interface. Beyond viewing, users can annotate reports and share insights directly through the app. Reports can be displayed on various mobile screens, such as phones and tablets, enhancing operational agility and support efficiency.

Members of a workspace can share specific customized views of a report with colleagues via a simple URL, provided that the shared report corresponds to the platform (desktop or mobile) of the recipient device. Regardless of the viewing platform, mobile users benefit fully from row-level security (RLS) implemented in the dataset. Furthermore, filtering and slicing capabilities allow users to access the precise data they need, ensuring a tailored and secure business intelligence experience.

7. Power Query

Power Query makes the relationship between Power BI Data Sources and Data Modelling more navigable by showing the type of data transformation involved before creating the Data Models and Visualizations. The section begins with a look at the Power Query Interface and then explores common data transformations. Finally, it touches on the M language that provides a flexible, effective, and powerful data transformation capability.

The Power BI Data Sources feature can pull data from many systems, and each system's data displays differently [16]. Collections, tables, and even each field brings varying data into the Power BI model. Equally important are the efforts creating tables of data structures that are a part of the relationship between the data sets to provide meaningful data insights. Power Query also plays an important role in creating unique insights through calculated columns, using practical use-case examples.

7.1. Data Transformation Techniques

Data transformation—the cleansing, filtering, and shaping of data—is a foundational task in Business Intelligence and analytics design and development. Power Query simplifies the process through built-in transformations, but advanced and customized requirements call for the M programming language. This section introduces M and provides an overview of fundamental functions [9,16-18].

Power Query can connect to hundreds of data sources, encompassing on-premises, cloud, software as a service, and even web content. Data is imported and transformed within the Power Query Editor interface.

7.2. M Language Basics

Understanding the M Language is essential for mastering data transformations within Power Query. While the graphical interface allows users to perform operations through direct interactions, each action records a corresponding M statement behind the scenes. Delving into these statements offers deeper control and flexibility for data shaping tasks.

Consider the structure of an M query that begins by sourcing sales data from a CSV file. The resulting procedure includes commands to promote header rows, remove undesired columns, and alter column types. Even though the user might execute these changes via the user interface, unraveling the generated M code clarifies the underlying mechanics [2,19-20]. The introductory keywords of each step—such as 'Source', 'Promoted Headers', 'Removed Columns', and 'Changed Type'—signal the nature of the transformation being applied. Familiarity with these elements enables more informed and sophisticated data preparation routines.

8. DAX (Data Analysis Expressions)

DAX, or Data Analysis Expressions, serves as the functional query language for Power BI, Excel Power Pivot, and Analysis Services Tabular models. Its primary role involves performing calculations and queries on data within tables. Power Query handles the initial Data Transformation and Modelling phases, loading the data into the Power BI data model, whereas DAX defines Calculated Columns, Cities, or Queries for slicing and dicing the data during the report's visualization.

DAX supports a variety of functions, including mathematical operations (such as SUM, AVERAGE, COUNT) and date/time calculations (like DATEDIFF and DATEADD). Calculated Columns stem from earlier Data Modelling stages when the model requires computation in addition to the loaded data. Calculated Measures, on the other hand, aggregate information using DAX Functions whenever necessary. Lastly, Calculated Tables represent subsets or filtered versions of the main data model, allowing custom filtering within the Power BI report.

8.1. Introduction to DAX

Much like Power Query transforms and prepares data input, DAX extends analysis capabilities by helping create calculations and aggregated metrics. Both features are essential to Power BI and form the foundation for advanced calculations and analytics. Data Analysis Expressions, or DAX, is a powerful language designed for creating custom calculations in Power BI. DAX formulas can perform complex mathematical operations on data, essential for generating calculated columns and measures that enrich reports with insightful metrics. Calculated columns add new data fields within tables, whereas calculated measures offer aggregated insights computed on the fly during query time.

DAX employs a combination of arithmetic, comparison, and logical operators to define these computations. It supports numerous functions, including those from Excel like ABS() and SUMX(), as well as specialized DAX functions such as DISTINCT(), RELATED(), and CALCULATE(). In Power BI, DAX expressions can be applied not only to Power Query-driven tables but also to any tabular data source, encompassing Excel, SQL Server, and Oracle.

8.2. Common DAX Functions

Functions are the workhorses of DAX, performing easily defined formulas and calculations. Listing all DAX functions and capabilities is impractical; instead, the focus here is on some common and interesting ones, while the Microsoft DAX reference is an excellent further resource.

DAX functions fall into several categories: Aggregate, Date and Time, Filter, Logical, Mathematical and Trigonometric, Statistical, and Text. It is worth noting that DAX lacks native text functions.

8.3. Creating Calculated Columns and Measures

Calculated columns can be created in the Power Query Editor or the Data view in Power BI Desktop. In the Data view, select New Column and enter the required expression using the DAX language to create the column. Entering the desired column name followed by an equal sign initiates the editor. The DAX editor highlights recognized functions, assisting in correct function use.

Measures perform calculations on aggregated data within the filter context, returning a smaller, summarized set. They can be created by selecting New Measure, which triggers a pop-up box; enter the expression and click the check mark. Power BI automatically formats the result with default settings such as $ and percent. A common measure example is Total Sales, created by summing a measure column with Sales Amount.

9. Power BI and Azure Integration

Microsoft Power BI naturally integrates with Azure's cloud services and infrastructure. Additional features enabled by integration include Advanced analytics, Enterprise ready built on Azure, and Power BI Embedded. Azure API Management combined with Power BI embedding allows an organization to build a secure and scalable analytics portal for external users. Solution developers can use Power BI to create analytic solutions with beautiful interactive charts and reports, and then Power BI Embedded API to embed the visuals into their applications [9,21-23]. Such a portal could provide Business Intelligence based on an organization's product or service data for their customers. Customers can register and subscribe for the service plans from the portal and the above combination takes care of securing the analytics pages from unauthorized access.

Power BI provides some pre-canned content pack services for Azure products like Azure HDInsight and Azure Audit Logs. Data from these two services can be used to create rich reports and dashboards within Power BI with its direct connection to HDInsight clusters. Power BI also supports an "upload file" interface for Excel and .csv files. A user can create these files in multiple ways using Microsoft Excel and Azure HDInsight Microsoft Excel Add-ins.

The Azure

9.1. Using Azure Data Services

In the early days of Business Intelligence (BI), data typically originated from internal systems—databases, tables, spreadsheets, CSV files, and so forth. Each data source required its own extract, transformation, and load (ETL) process to prepare, cleanse, and implement complex data transformations. It was essential to have a reliable data source, centralizing the complex ETL workload into one place. However, BI has evolved in step with technology, allowing us to incorporate not only internal data but also external sources, such as social media, RSS feeds, and Facebook, as well as sources located closer to the cloud.

Since Power BI is a component of Microsoft Azure, we have the ability to analyse data stored in the cloud through numerous Azure services, including Azure SQL Database, Azure Data Lake, Azure Blob Storage, and more. As with in-house data, complex ETL processes are often necessary to transform the data before incorporating it into Power BI. Azure provides numerous services, both in the PaaS (Platform as a Service) and IaaS (Infrastructure as a Service) categories, for this purpose. For example, Azure Analysis Services and Azure Data Factory are PaaS services commonly used to address the ETL requirements for Power BI.

9.2. Power BI Embedded

Power BI Embedded is a collection of Application Programming Interfaces (APIs) and client libraries, all hosted within Microsoft Azure. The fundamental idea behind Power BI Embedded is that user-level features and controls available through the Power BI service are also accessible to application developers and independent software vendors (ISVs). Developers can embed these features into applications, establishing a single relationship between the application and the Power BI tenant, which then facilitates features supporting multi-tenancy within the application [24-26]. ISVs can utilize Power BI Embedded to permit tenants or customers to log into their application and access Power BI without the necessity of creating a tenant or customer account within the Power BI service.

Power BI Embedded enables developers to access Power BI reports and dashboards and embed them within custom business applications. Developers have full control over features like report navigation, dashboard filters, and bookmarks, allowing them to provide better user experiences. They can also create new reports and publish them to existing workspaces for their users or customers. Power BI Embedded supports several use cases, including Embedded analytics, Customer-facing analytics, and Internal-facing analytics. Additional functionalities include REST API maintenance tasks for Power BI resources. These capabilities are available through the Microsoft Power BI SDK for JavaScript development, facilitating enhanced customization and integration within applications.

10. Real-world Use Cases of Power BI

Power BI is enabling analytics in every industry imaginable. Two illustrative examples—financial analytics and marketing insight generation—are followed by links to other demos. These real-world applications demonstrate how a creative analytics team can significantly increase productivity and improve the user experience.

The Financial Analytics demonstration uses Power BI with SharePoint Online and Excel to analyse cash payments made during April's budget period. In this example, budget analysts created Power BI reports and dashboards that showed spending by categories such as account, vendor, employee, purpose, and transaction date [8,27-30]. These visual presentations helped both end users and managers easily identify spending trends. In the Marketing Insights demonstration, salary survey results were imported from a CSV file for respondent age, function, industry, and salary. Marketing analysts created Power BI reports and dashboards that display the variance of each segment against the overall population. A handful of filters were placed on each visual to let end users explore that particular segment, and colour was added to highlight the segment's variance from the overall population.

10.1. Case Study: Financial Analytics

A financial performance report created with Power BI showcases revenues and profits for the past three years, both in actuals and forecasts. It also identifies the causes of revenue decline and tracks related key performance indicators (KPIs).

Power BI’s ability to swiftly generate charts and heat maps based on underlying data sets is demonstrated by profits and expenses presented as one-page heat maps. Heat maps for product forecasts compare product revenues for 2015 versus 2016, categorized by product and market, while revenue variations are mapped by region. Key insights highlight the effect of currency fluctuations on revenues and the reversal of past loss-making markets. Expense categorization uses calendar quarters as well as month and year hierarchies.

10.2. Case Study: Marketing Insights

Business Intelligence (BI) is defined as the process of analyzing current and historic business data to discover trends, patterns, and relationships between data points. BI systems provide the ability to present the analysis and display business-critical information on dashboards and reports so that the business can be proactive, identify opportunities and threats, and improve customer relationships.

Power BI offers a complete umbrella of services and capabilities scoped to deliver efficient Business Intelligence across the organizational data landscape [9,31-33]. For disparate data spread across the enterprise premises and cloud, Microsoft offers Microsoft Power Platform with Azure services for streamlined data management and connectivity, so that the data is easily available for decision-making. Microsoft Azure provides a collection of several services that help in meeting different BI and AI needs:

These integration capabilities enhance and expand the collaborative power of the BI ecosystem and enable Business Intelligence at an enterprise level with role-based security. Azure integration helps applicable Power Platform services to connect Power BI data and visuals; it further allows BI reporting functionalities to be embedded in Azure websites and app services for both vendors and customers.

11. Best Practices for Power BI Development

Numerous free resources are available to help Power BI users get started, including the official Microsoft Facebook page, YouTube tutorials, and comprehensive documentation [34-36]. Exploring additional capabilities such as Power BI Embedded and Power BI for Azure enhances the Power BI ecosystem and supports advanced data-related scenarios. Optimizing Power BI reports begins with data analysis, followed by appropriate front-end and backend design choices; here, DAX plays a vital role.

Power BI Desktop enables effective visualization presentation, but sharing options vary in complexity and applicability. While the Free license facilitates publishing on the Web, the Pro license supports dashboard sharing within the organization. The Power BI Premium license offers extensive backend enhancements and storage capacity. For real-time data, Power BI Streaming

Datasets—using the API—are recommended. Microsoft Power BI's strength lies in its ability to address a wide array of business requirements, including maintenance, finance, marketing, and point-of-sale analytics.

11.1. Performance Optimization

Building highly performant dashboards is essential for the overall success of the solution. Users often interact with several report pages, and if the initial page is slow, it may take too long to render other report pages. Therefore, developers should begin optimization as early as possible and monitor performance on an ongoing basis.

The Power BI community provides several best practices covering various aspects of performance. First, data in the Power BI Desktop is stored inside the in-memory engine. The maximum supported memory capacity for a dataset is 1 GB, so models should be optimized to fit into the memory constraints of the Power BI dataset engine. Second, the size of the data model is a critical criterion in performance. To reduce the data model volume, Power Query can be used to remove unnecessary columns, change data granularity, and filter out unwanted rows directly in the data source. Filtered tables should also be excluded from refresh if possible [3,37-39]. The third aspect is optimization of calculations. Calculations should be optimized with minimum complexity in both Power Query (M) and DAX. Calculated columns are not dynamic, because they calculate their value for each row when a refresh happens; on the other hand, measures are calculated on demand and offer significant performance enhancements but can only be created at the table level.

11.2. User Experience Design

The ability to enter comments or add custom notes can help provide additional clarification or context, as well as engage users and encourage them to react accordingly. For example, an analyst may want to add a comment highlighting an important development, or an executive deciding on the next steps may want to add notes to document their insights and decisions.

Complex datasets and visually unappealing charts may confuse the report users and cause them to miss key takeaways, which can be avoided by making the right design choices. Power BI offers various customizations such as changing the colours, fonts, layouts, borders, and more for making the report more visually appealing and at the same time simpler to consume. Designing a great user experience is simply a matter of understanding suitable customizations and applying them correctly.

12. Future Trends in Business Intelligence

The integration of emerging technologies into Business Intelligence (BI) is swiftly transforming methods of data analysis and decision support. Artificial Intelligence (AI) plays a pivotal role in this evolution by enabling Autonomous BI, which automates the generation of explanations for outliers and presenting insights in natural language. AI-driven visual analysis leverages natural language queries and image-processing capabilities to create custom visuals, enhancing continuous data analysis. Data governance functions increasingly incorporate AI through natural language processing techniques, which augment metadata with conversational tags and simplify access controls.

The confluence of BI and Artificial Analytics is revolutionizing modern enterprise operations. BI software now employs deep learning and computer vision to analyse structured and unstructured data, routinely generating insights. Natural Language Processing (NLP) supports conversational interfaces, allowing users to interact with dashboards via speech or text. Chatbots and digital assistants interpret these inputs, responding with executable insights, complete drill-down capabilities, and summaries in natural or speech language. Automated decision-making and execution rely on persuasive analytics to suggest courses of action. These advances have led to the introduction of Power BI Copilot, integrating recent Microsoft research technologies to provide conversational capabilities like ChatGPT within Power BI.

12.1. Artificial Intelligence in BI

Artificial intelligence continues to make inroads into all stages of the business intelligence process, ranging from data preparation, to building machine learning models, to data exploration, to acquiring business insights and explanations. Finally, intelligent technologies are becoming important to the role of data governance for BI, and Power BI now features AI-categorized data sensitive labels. Power BI offers numerous cognitive services to enrich the data and produce visualizations. The integrations include Machine Learning and Cognitive Service APIs from Azure as well as the Cognitive Services connectors for Azure Blob and Azure Table facilities. The cognitive connectors enable data cleansing and data enrichment [36,40-42].

The Power BI service built on the Azure Machine Learning service supports two approaches. One approach enables creating and training machine learning models through Azure Machine Learning Studio. The newly trained model can then be tested and published as a web service. The Azure Machine Learning web service can then be called from Power BI Desktop or Power BI service as an action on data. The second approach leverages Azure Services from Power Query in Power BI Desktop. Power BI Desktop enables calling a Power Very Simple Prediction (VSP) machine learning model to predict values for input data. Likewise, Power Query enables calling other Azure Cognitive Services, such as language, visual, text, and speech. Additionally, Power BI Desktop supports integrating R-scipt visualizations into reports.

12.2. The Role of Data Governance

Business intelligence nurses a paradox at the foundations of the entire data-product development business: the lengthy, tedious, and error-prone process of funneling data into dashboards and reports of key metrics can make all the difference between giving a business the necessary insight and knowledge, or an imaginary insight leading their business to failure. With a growing number of users and contributors, BI reports become workshops of living ideas for any business—growing, refining, and evolving to include all pertinent key indicators [40,43-44]. However, the ever-expanding constellation of Power BI reports can also sit scattered and unmanageable, with security waning, awareness falling, and development skills decaying.

From a data-gov perspective, the question arises: "which users are both a threat and can mitigate risk?" Enterprise Data & Analytics teams might look to championing and collaboration within a Power BI user-base—whether business, IT, or development. Such teams are armed with governance and risk-aversion tools, and armed with the skills and best-practice-awareness, they can wield Power BI as a shield rather than a threat.

13. Conclusion

Business intelligence is about getting the right information at the right time to the right people in the right format so they can act on it. Power BI enables the delivery of information so that users can make decisions based on data instead of gut feeling. Power BI is a complete solution—offering infrastructure, reports, transformers, burnout, and presentation layers in one place and supporting both open-sourced and Microsoft proprietary technologies.

Power BI offers benefits over other BI tools by integrating the components that once formed an ecosystem into a single product. Even though Power BI contains many components, they come bundled inside a single package. With Power BI Desktop, business analysts can develop a corporate portal that contains datasets uploaded from Power BI Desktop. Setting up a cluster can establish a user access control environment. Power BI Desktop includes an embedding feature that enables developers to embed Power BI reports inside their applications.

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Chapter 3: Visualizing with Tableau: Creating Interactive Dashboards

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[1]*Decision Ready Solutions*
[2]*First American Title*

1. Introduction to Data Visualization

The crux of the burgeoning era of Big Data and its practical deployment using data analytics and business intelligence tools lies not only in data visualization but also in the enriched meaningful information leading towards better decision-making. Although the meaning and role of data visualization have been explored and argued at length data visualization represents the means through which the data that resonate with the human visual system are better exploited. It is the art and craft of both acquiring high-dimensional data and leveraging the capabilities of visual encoding channels to convey messages effectively and efficiently. Using visual representations and infographics, it aims at communicating and illuminating the effectively organized data and information. Data visualization comprises lists of guiding principles supported by an alternating series of summarizing tables, a catalog of common chart types, and a list of charts connected to these principles. Thanks to the design of scaled objects in physical displays, the users could see the information within a data set, and are able to note the trends and patterns, compare and group, find exceptions, and finally understand the data.

Software products such as Tableau are specifically designed to address the need of publishing information on the Web and to support an unlimited number of end-users without the need of Tableau licenses [1]. The Tableau product suite is currently ranked as the leader in the Gartner Magic Quadrant for Business

Intelligence and Analytics Platforms for the eighth consecutive year. Tableau is a powerful and fastest growing data visualization tool used in the Business Intelligence Industry. It can connect to files, relational and Big Data sources to acquire and process data. It allows the creation of interactive and shareable dashboards. The dashboards depict the trends, variations, and density of the data in the pictorial or graphical format which is easy to comprehend for the users. With the help of these dashboards, actions can be taken immediately based on the data presented. Interactive Filters allow users to explore the data with different angles easily. Tableau workbook can be published to Tableau Server, Tableau Online which allows others to interact with the report and download the data for further analysis.

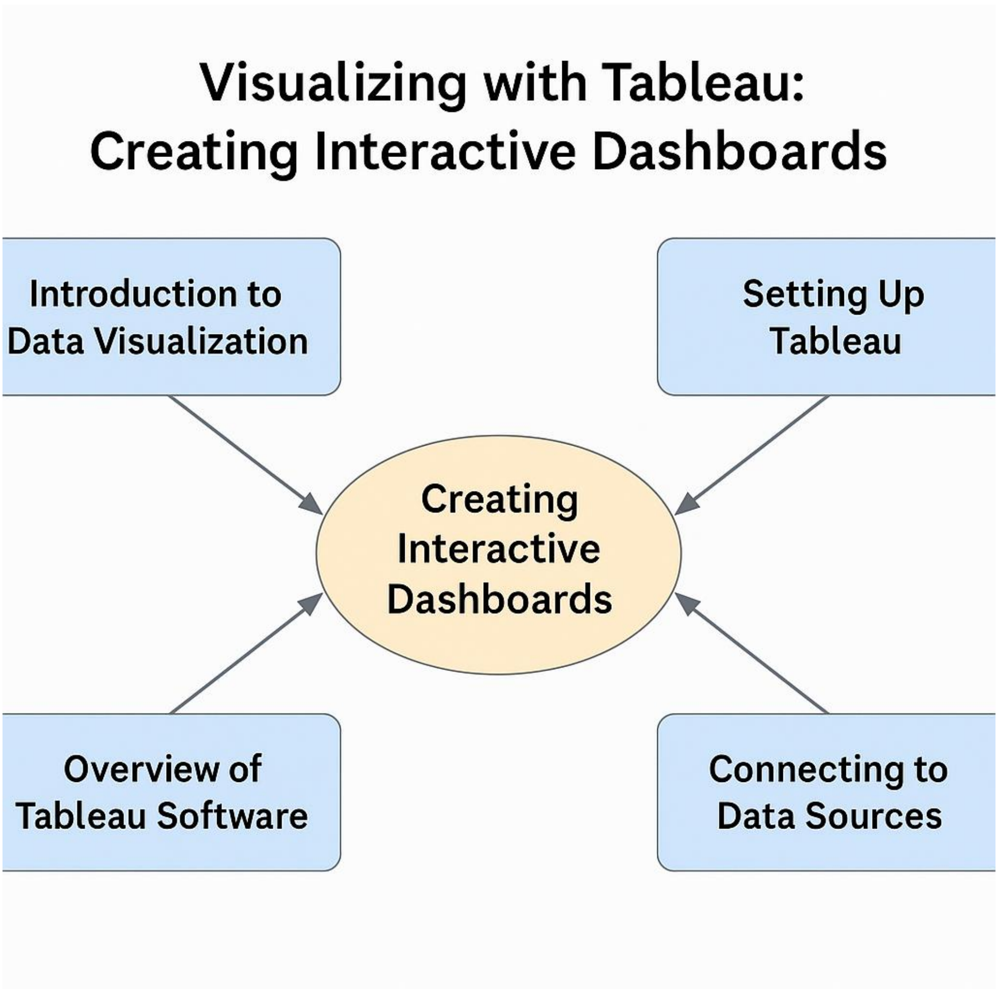


Fig 1. Visualization with Tableau

2. Overview of Tableau Software

Tableau is a powerful data visualization software widely used in the business intelligence industry. It allows for the creation of an interactive, data-driven environment to explore complex datasets [1-2]. Tableau’s advantages include a user-friendly interface, the ability to connect to various data sources, and offerings for both commercial and personal users.

Industries such as business, health, education, and many others employ Tableau to visualize data, glean insights, and make sound data-driven decisions. The software provides a simple means for analysing extensive amounts of data, enabling users to detect hidden trends and relationships quickly.

3. Setting Up Tableau

Visual data exploration plays a vital role across almost all sectors. Graphics help experts communicate knowledge they hold—be it numbers, statistics, or trends—much more effectively. People grasp concepts and relate to stories better with images, so information is more likely to persuade, relate, engage, and educate. In sales, business, healthcare, education, and beyond, dashboards convey core messages to help make critical decisions.

Tableau is a leader in the visual analytics and business intelligence market segment. Setting up Tableau involves installing Tableau Desktop and connecting to data sources. When the software is installed on a computer, it appears in the Start Menu or all apps list [3-5]. Launching it presents the Tableau start screen offers options to connect to data and create visualizations. People can link to data they cleaned and saved or to other sources including their computers or disks, and to online data sets on websites or cloud services. A dedicated section containing specific data connection options appears.

3.1. Installation Process

Setting up a Tableau environment begins with installing the software on a dedicated workstation. The installation package can be obtained by signing in to the official Tableau website on the products page with the appropriate credentials. Although the current example uses Tableau Desktop, different packages offer similar services and might be more suitable depending on the user's goals. After selecting the 'Download' button, the program automatically downloads to the device.

Upon completion, launching the software initiates the setup process. The initial screen prompts sign-in or license key entry; users opting for two weeks of free service select the 'Start Trial' button, leading to the normal operating mode. Tableau supports connections to a multitude of data sources, ranging from traditional file formats (Excel workbooks, delimited text files, statistical workbooks, data extracts) to servers and sites (Microsoft SQL Server, Salesforce, Google Analytics, Oracle, among others). These options ensure that real-time data can be ingested from nearly any place on the internet.

3.2. Connecting to Data Sources

After installing Tableau, the next step involves connecting to a data source. Selecting "Connect to a File" presents multiple choices, encompassing Excel spreadsheets, text files (.csv/.txt), JSON files, PDFs, Spatial files, Statistical files (.sav) data extracts, and Microsoft Access. Conversely, "Connect to a Server" includes various server options: Microsoft SQL Server, Excel Services, Oracle, OData, MySQL, PostgreSQL, IBM DB2, Google BigQuery, Microsoft Analysis Services, Teradata, SAP HANA, and Splunk.

Once a suitable data source is chosen, Tableau automatically fetches the information and displays it in the Source tab of the Workspace. In this stage, users can inspect their data, undertake cleanup operations, or execute fundamental transformations, thereby preparing the data for the creation of insightful visualizations.

4. Understanding Tableau Interface

The Tableau interface features several main components. The data pane contains dimensions, which hold categorical data, and measures, which hold quantitative data [6-8]. Tableau automatically assigns geographic roles to certain dimensions (Country, State, City, and Postal Code). The information provided for each province in the later map of Australia example is obtained by highlighting the province and the associated Province Info section.

The middle of the interface contains the center pane, which allows for the creation of worksheets, dashboards, and stories. The bottom of the interface

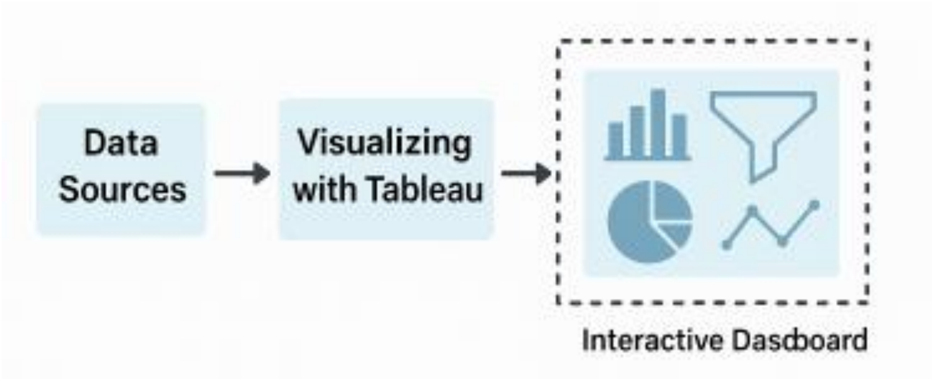


Fig 2. Tableau interface

contains tabs for selecting one of these modes. Above the tabs is the shelves area (Pages, Filters, Marks) along with the Columns and Rows shelves. The Tableau data type is also shown for each variable (string, number, date, geographic role).

4.1. Main Features

The Tableau interface layout includes several important features. The Data window holds all the fields of the connected data source. It allows the creation of calculated fields, new sets, parameters, and groups. Selections here can be dragged to the Columns and Rows shelves to visualize data in rows and columns.

The Workspace area displays the data visualization under development, with the tree of sheets at the bottom. In the Data pane, dimensions and measures are displayed in blue and green, representing Discrete and Continuous fields respectively [9]. The Display pane shows tabs for Worksheets and Dashboards. The Pages shelf supports visualizing different values of a selected field through animation. The Marks area contains controls such as the Marks type drop-down and options for Colour, Size, Label, Detail, and Tooltip.

4.2. Navigating the Workspace

After setting up Tableau and connecting to your data, the next step is to understand the workspace interface. All Tableau activities — creating basic visualizations, applying advanced charting techniques, or compiling the display into interactive dashboards — take place within this environment.

The workspace comprises three key areas. The sidebar contains the Data pane, displaying all data from the connected source(s). The middle section includes a plethora of tabs and menus for settings, filters, annotation, formatting, and illustrations. The space at the back is for creating and viewing dashboards, stories, and sheets.

5. Data Preparation Techniques

Data Preparation Techniques Data cleaning and transformation are crucial preparatory steps ensuring that analyses and visualizations rest on accurate data. Junk, incomplete, or corrupted data can produce misleading outcomes, which can be costly when analyses underpin decision-making. During the data preparation phase, analysts assess each column's contribution; data added merely for completeness but without analysis relevance may, in fact, clutter and confound the model. The objective is to provide Tableau with seamless and continuous access—the resulting visualization is derived from continuous connectivity [7,9-10].

Gathering Data Establishing an analysis framework before proceeding is advisable. Understanding the key information stakeholders seek enables the data collector to assemble the required raw data in the correct foundational structure. This prerequisite shapes the techniques for extracting, transforming, and loading the data (ETL) into the Tableau data engine. Assessing the database size helps determine data volume and memory requirements. Upon meeting assessment criteria, the gathered data tables can be saved in a file format compatible with Tableau for presentation and analytics on the desktop platform. Tableau supports a variety of usage types—business intelligence, web authoring, embedded analytics, or mobile solutions—facilitating seamless connectivity and interaction with data.

5.1. Cleaning Data

Before creating visualizations, it is useful to prepare the dataset first in order to improve the output of the analyses. Datasets are often incomplete, dirty, or unsystematic; data preparation involves cleaning and transforming the data such that it is suitable for visualization [1,11-14]. Tableau software is able to perform several data preparation techniques on the data source connected to the workbook.

Data Cleansing Data cleansing includes procedures such as renaming field names, changing field data types, hiding fields from the Data pane, and translating field aliases. The associated Data pane allows renaming of the fields through a right-click action and selecting Rename [13,15-17]. The Data Type can be changed from a right-click action and one of the Data Type options can be selected. Tableau can interpret a field of number data type for visualization, but when that data represents a Category, a change to String is needed. Nonrelevant fields can be hidden from view and will not be available for visualization by right-clicking and selecting Hide for the intended field. When a field contains values that are either not well labeled or cannot be understood by the Tableau dashboard user, the field aliases can be updated by right-clicking the field containing the values to be modified Aliases are typically used to change an abbreviation to a more descriptive text (e.g., changing CA to California).

5.2. Transforming Data

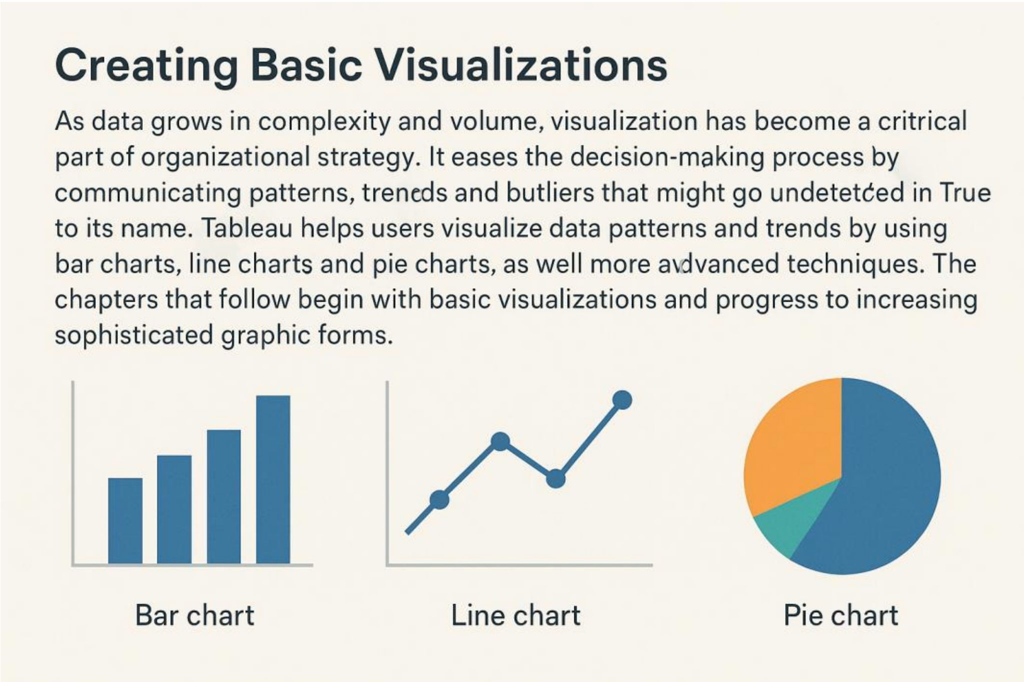
Preparing data for analysis in Tableau is the next step after initial transformation to cleaning. The data-cleaning process typically entails removing duplicate rows, renaming heaps letters, eliminating negative values, selecting specific columns for analysis, and converting the data type of values. Tableau Prep provides numerous wizard-driven pages that simplify the cleansing of data for analysis. Users can subsequently create visualizations and dashboards based on the cleaned data [18-20]. Remember that data preconditioning enhances data sources so that subsequent needs are not overly reliant on complex data transformations. It is important to outline data preparation tasks before starting to construct reports.

Consider another example involving an online retailer that collects transactions from customer orders delivered around the world. The retailer collects the data, although it is valuable in its aggregated form as data: salesperson, country of delivery, sku, quantity, sales, cost, margin, customer name, salesorg, and salesregion. A myriad of additional data preconditioning might be required, but the focus here is simply on how to construct a basic visualization given data aggregated within Excel.

6. Creating Basic Visualizations

As data grows in complexity and volume, visualization has become a critical part of organizational strategy. It eases the decision-making process by communicating patterns, trends and outliers that might go undetected in datasets [19,21-22]. True to its name, Tableau helps users visualize data patterns and trends by using bar charts, line charts and pie charts, as well as more advanced techniques. The chapters that follow begin with basic visualizations and progress to increasingly sophisticated graphic forms.

The program can connect to a vast range of data formats including plain text, Microsoft Excel, Microsoft Access, Microsoft SQL Server, JSON, PDF, and SAS. Acting as a bridge between the data source and the user, Tableau simplifies advanced analyses and offers basic techniques for data preparation and manipulation. Bar charts, line charts and pie charts help build the foundations; together, they address many of the questions users normally ask of the data.



6.1. Bar Charts

Bar charts are one of the most popular chart types for visualizing relational data that includes discrete categorical dimensions and a corresponding quantitative measure [11,23-25]. In the example visualization, the categories on the discrete Dimension Axis are each department of a company and the Axis Measures represent the Total Expense for the corresponding department and month. The axes intersect at the zero point. Bars of different heights extend either upward for positive values or downward for negative values from the zero point on the vertical axis.

Each Category is grouped into a cluster or stack, depending on the colours of the Slices. Adding a Slicing dimension splits the bars in close proximity to give an immediate indication of the size of sub-categorized groups within each of the main categories, much like submitted bids for a company's downtown project from different local construction companies in different industries (Engineering, Material Supplier). Creating stacked bars that add up to the total for the grouped bar is also simplicity itself.

6.2. Line Graphs

After entering the first visualization using a Bar chart, return to the Data Worksheet and create the second dimension: Change the Mark Type to Line.

Now add the "Sales" measure: Click on SUM(Sales) and drag it to Rows. By default, Tableau creates two axes, one for each measure. This behaviour can be avoided by dragging the second measure over the first. When the darker strip appears around the first measure, release the mouse. Now there is only one Y-axis and the two measures share it.

6.3. Pie Charts

Pie charts can be a useful tool if the sequences are short, for example, less than 6–8 members. Pie charts can be used to display the relationship between sum of sales for different years and division member. Fig. 6.18 shows a simple pie chart that shows the relative contributions of division sales for the different years. All the three Pie charts are positioned next to each other.

The pie chart was created using a circle mark. The division member is the colour, and the size shows the sum of sales for the different years. For the exploded pie chart, the colours are assigned using the number encoding, where number encodes "Yes" and 1 encodes "No." The group member has been added to a detail card.

7. Advanced Visualization Techniques

The previous section introduced the creation of basic visualisations such as bar and pie charts. Tableau also offers a wide range of advanced visualisation types, including heat maps, highlight tables, scatter plots, histograms, bullet charts, and geographical maps [26-28]. These visualisation types are particularly useful for creating interactive dashboards. By combining different types, the key metrics can be clearly and concisely displayed, providing users with a complete overview of the data.

Heat maps represent data frequency where colour intensity indicates the intensity or concentration of a particular metric value. Highlight tables also represent data frequency. A scatter plot is an effective way to visualise the correlation between two variables, with two columns or rows being displayed as points on the marks card within the visualisation. Histograms are modification of bar charts, representing the distribution of a continuous variable, with the bars representing intervals or bins of the variable. Bullet charts are a variation of bar charts, allowing the denotation of a target within the bar chart, and are often used in executive-level dashboards to provide a comparison between actual and target performance. A map visualisation plots data in relation to a geographic location based on longitude and latitude. The values of a chosen measure are represented on the map by differing shades of colour.

7.1. Heat Maps

Cross-referencing is a fundamental tool for scholars, helping articulate the credits for ideas and evidence. Yet in ever-growing volumes of scholarship, it serves perhaps its most compelling use: enabling the reader to chart their own navigation through the text, toward deeper understanding. Readers contemplating the creation of basic visualizations such as bar, line, or pie charts should refer to section 6. Creating Basic Visualizations, and those seeking to integrate a variety of charts into interactive dashboards should consult section 8. Building Interactive Dashboards.

Heat maps visualize tabular data through the intensity of colours in a range of native Tableau charts. This can be combined with page marks for scrollable data display. For example, adding Postal Code to Page and Member to Colour to a Heat Map quickly reveals variations in members for the postal codes within a state. Larger values can be highlighted using Count and the attribute Average of Count of Members. Visual encoding is enhanced for tile shading by clicking Colour and selecting a suitable palette. Other fields that might be visualized using encoding include Id, Event, Home Depot store, Inventory Group, Document Number, and Product Category.

7.2. Scatter Plots

Scatter plots allow correlation or relationship between two of their measures. These plots display distribution shapes, concentrations, and identify outlier values that appear away from the main distribution [29-32]. A scatter plot uses plotted circles to display values for the two measurement variables. The data are plotted as points using the two supplied measurement columns, one for each coordinate. The position of each circle obviously can indicate the value of each measure, but the other measures can be used to provide the size and colour of the circles.

A few lead-in examples help to understand the notion of this corner of the story. In the Scatter Plots area of the Tableau show case, click Scatter Plot Interactions. The Scatter Plot interactions show the visual relationships between states as the year changes. The scatter plot uses population and sales as its two primary measures, with a year-based playback that shows the relationship between the eight selected states for each year. The colour indicates the region, and the size relates to the square miles of each state. Next, in the Scatter Plots area of the show case, select Body Mass Index. This plot plots the individual values of height and weight for a selection of men. You can select any branch of the upper tree to see the individual values for those two measures. Then, from the same section, select BMI by Races. Here, the average heights and weights are plotted for the different races of men in the sample. The size of the lung sets the actual numeric values and helps us understand where the average within each group lies.

7.3. Geographic Maps

Geographic maps stand out among data visualization techniques because they display location information alongside other related data. When geographic locations are involved, Tableau offers a variety of mapping functions [31,33-35]. There are several types of maps: traditional maps used everywhere, filled maps that provide a colour fill to clearly distinguish each geographic region, and density maps that highlight areas of high concentration.

Maps are most effective when both dimension and measure fields related to location data are present in the view. Tableau automatically generates geographic maps whenever geographic fields—such as country, province or state, city, and zip code—are used as dimensions. By default, Tableau utilizes the first such field added to establish regional boundaries on the map. Additional address information, including street, postcode, and country, is also recognized by Tableau and can be incorporated to enhance the map's detail.

8. Building Interactive Dashboards

The creation of interactive dashboards is one of Tableau’s most powerful features. Dashboards are a collection of views from one or more worksheets, offering the user a comprehensive snapshot of entire datasets. While standard web pages can display images or text together, Tableau dashboards can present web content, spread sheets, or combinations of local and browser-scoped feeds and dashboards.

The key elements of a dashboard include views, filters, legends, and web objects. A view is a functional web page displaying visualizations, such as a heat map. Filters and legends enhance navigation and understanding, while web objects modify the browser window's HTML scripts. Filters can be applied to all views on a web page; for instance, selecting a country in one view causes the maps in other views to adjust accordingly. Actions provide interactive control over filtering and final-point highlighting in and across visualizations. They help create navigable and dynamic dashboards where readers can delve deeper into their data or move intuitively through the displayed views.

8.1. Dashboard Components

Certain components are fundamental to creating any Tableau dashboard. A dashboard without visualization would be like a car without a steering wheel—it may be technically functional, but it would serve little purpose.

Tableau enables the compilation of multiple charts to assemble the desired story. Table calculations— such as rank, moving window average, total percent, and difference— provide the necessary analytical purpose. Additionally, filters facilitate user interaction. Additional features are added during the assembly phase to make the dashboard engaging and appealing.

8.2. Using Filters and Actions

Filters control what data is displayed in a view. Generally, only the different data items displayed in rows and columns of a view are available for filtering. One of the key features of Tableau is that it allows for several different filters to be set on different data levels:

• Data source filters • Extract filters • Context filters • Dimension filters • Measure filters • Date filters • Table calculation filters

Actions add interactivity to dashboards and worksheets. Filters applied through Actions are a powerful tool to create an engaging and dynamic user experience. The key types of Tableau actions are:

• Filter actions • Highlight actions • URL actions

Interactive dashboards usually contain complex navigation between different sheets; the use of Actions helps to create a seamless experience. The possibilities of using Actions can be very broad—for example, by combining Highlight Actions with the complex use of Colours and also combining URL actions with another JavaScript API.

9. Enhancing Dashboard Aesthetics

Creating a Tableau dashboard that is both visually appealing and interactive elevates user engagement and maximizes business value [36-38]. Adding filters to dashboard objects allows viewers to manipulate actively the display set, updating the visualization accordingly. Filters introduce movement to the interface, lessening the sense of dead-ends common in static charts. The next step in dashboard design—adding page, category, and range selectors—further enriches interactivity.

Strategic use of colour enhances aesthetic fun while improving readability and visual consumption. Colour treatments can draw attention to specific behaviours or trends and add different dimensions of information within a single display. Colour choices affect viewers psychologically; colour theory, together with typography and layout, constitute visual design theory, a central concern in graphical dashboards.

9.1. Colour Theory in Dashboards

Colour theory in dashboards is. Using the right colours is essential in visualization, for both the logical interpretation of categories and values and improving the appearance of the whole picture. Tableau offers several colour options that are closely related to the data type. It is also possible to edit the colours or choose specific colour sequences from several palettes. Colour usage should follow the best practices discussed below.

The human eye can perceive about 7 or 8 different hues in a picture. Thus, it is recommended to limit the number of different colours or hues in a visualization—for example, less than seven categories if the colours represent categorical attributes. Colour groups—a set of colours resembling a similar hue—should be avoided unless there is an intended hierarchy. Colour blindness influences the understanding of any visualization based on colours. If colour is the only property used to distinguish between categories, it is expressed as a big problem.

9.2. Typography and Layout

After colours, typographical elements represent the second cornerstone of aesthetics; nevertheless, they can offer more than mere refinement [1,39-41]. Since 95% of dashboards compose text (labels, titles, legends, and so on), choosing convenient fonts can simplify and guide their understanding. The choice of lettering is deeply rooted in the personality of every culture. Characters have evolved through the years and styles, each linked to a different era in time. A large quantity of typographic services provides suggestions and pairings of fonts based on these aspects. Although not directly related to visualization, these services, if carefully selected, can greatly improve user experience by making dashboards less intimidating and more pleasant. As an example, a health-care dashboard using decorative fonts may be considered out of place, yet those very fonts could be a perfect fit for wedding planners.

Regardless of the neatness of colours and typography, a messy presentation of objects ruins the overall distribution of the dashboard [42-44]. In addition, due to the higher computational demand of filtered views, the main visualization should be arranged near the interactive objects to enhance performance. Within Tableau, a container box helps arrange images, texts, videos, or other boxes in a vertical or horizontal symmetrically distributed manner. Dimensions and paddings modify the space occupied by each element, while the appearance of every box can be stylized with a border. Smaller font sizes for subtitles and labels guide the viewer's attention, optimizing the time dedicated to visualization comprehension.

10. Publishing and Sharing Dashboards

Data visualization is a process that involves transforming data into graphical forms such as bar charts, pie charts, maps, lines, or dots. The use of these visual representations is becoming increasingly important because of the vast amounts of data produced by organizations and systems. Creating charts from these large sets of data helps present the information in a clear and understandable way.

Tableau is one of the leading data visualization software tools, providing services across various sectors, including business, healthcare, and education. After creating visualizations, Tableau offers multiple options for publishing and sharing the results [45-46]. The visualizations can be published to Tableau Public, Tableau Server, or Tableau Online, depending on the user's requirements. Dashboards may also be exported to PDF format, uploaded to Tableau Public for public web sharing, or saved as images to be shared through email or other messaging platforms.

10.1. Exporting Options

Publishing and sharing data visualizations is an essential stage of the process. Tableau provides the following three options. • Tableau Desktop Sessions. A Tableau Workbook or Tableau Packaged Workbook is a Tableau Desktop session saved to disk. A Tableau Workbook has the file type. twb and a Tableau Packaged Workbook has the file type .twbx. Both can be shared with recipients who do not have Tableau Desktop, but the recipient needs to have Tableau Reader installed

[18,47-49]. Tableau Reader is a free program that enables a recipient to view any visualization created in Tableau Desktop and saved in this format. A Tableau Packaged Workbook has the added advantage of having a local copy of any external files that were being referenced in the visualization. • Tableau Server or Tableau Online. A Tableau visualization can be published on Tableau Server or Tableau Online after signing in, enabling users to view the project in a Web browser or on a mobile device.

10.2. Sharing on Tableau Server

Once the Tableau Server is set up, existing sites and projects can be utilized or new ones configured. Publishing from Tableau Desktop requires server credentials and selecting the destination site and project. There are two options for integrating dashboards within the server environment:

- Default View: The initial dashboard displayed on the Tableau Server - Content Customization: Allows users to personalize the dashboards to meet their specific requirements

Publishing Tableau dashboards enables sharing in both public and private environments. Tableau Public offers a free service for publishing dashboards publicly. For privately sharing dashboards, enterprise editions of Tableau provide Tableau Server and Tableau Online [18,47-49].

Tableau Server and Tableau Online can be considered as the backbone infrastructure supporting the sharing services of Tableau. Tableau Online is a cloud-hosted product similar to Tableau Server; however, the product is managed by Tableau, Inc. Only Tableau Server and Desktop offer full authoring capabilities. Tableau Reader supports interaction with packaged workbooks, whether they are uploaded to Tableau Public or saved locally on a user’s system. If the data source is a live query, users can interact with the data just as they can on Tableau’s desktop application.

11. Best Practices for Dashboard Design

Once it meets the user objectives and is published, a dashboard is finished. Yet are there any ways to improve the design?

Whether a funnel chart is most suitable should be no longer be at the centre of the discussion, instead the focus should be on the user perspective. The corporate logo, a heat map with a blue gradient or another choice because a ring chart is easier to understand are all nuances of the final design. Other important aspects are performance and permissions.

11.1. User-Centric Design

Dashboards are designed to communicate insights for a range of users, each with different expertise, expectations and needs. It can be a challenge to address everyone's needs in one dashboard. The first element of good dashboard design is to understand who the audience is and what they need the information for. Keep the specific users in mind whenever a new visualisation is designed or the dashboard modified.

However, there are some elements that will generally improve most dashboards regardless of the audience. A report by the Nielsen Norman Group on usability heuristics emphasises that the design should help users recognise, diagnose and recover from errors [13,42-43]. Users are more likely to make input mistakes when they are busy or distracted, such as when working in a noisy call centre or on a crowded shop floor. Consider the environment the dashboard is being used in and design accordingly.

11.2. Performance Optimization

A slow dashboard will likely frustrate its users, especially if it cannot deliver the insights they are looking for in an efficient manner. Therefore, in the process of designing dashboards, it is important to also consider optimizing the Tableau workbooks to improve their speed and performance.

There are a lot of factors that can slow down the performance of Tableau workbooks. Some factors come from dashboards that contain too many visual components or display a massive amount of data. Creating complex calculations and using an excessive number of filters in the Tableau workbook can also affect performance. Data models with an excess number of fields that need to be processed by Tableau can put a big strain on performance as well. The way the data itself is stored and treated can act as performance bottlenecks, especially when a dataset is not cleaned so that it contains contradictory data records, blank columns, or unused fields.

12. Case Studies

Expanding in numerous business sectors, data visualization offers clear decisive solutions for many needs. Effective dashboards can reveal both internal and external insights. Some examples provide varied Tableau applications.

Tableau handles dynamic business needs across multiple domains. Operations managers may examine cost-saving actions, such as staff reductions or material usage. Typical questions cover contracting, overtime, and supply to assess impacts on efficiency. Analysis optimizes workflow and controls potential budget excess. Customer-service interaction also offers information for rating responsiveness and reliability. Special projects with defined timelines provide analyses for end-of-project-ranking of agents and teams [45-46].

The healthcare sector experiences a substantial growth potential. Tableau adapts to business-understanding queries, such as patient-care level and type, service delays and waiting times, and contract-management in handling with insurance companies. Focus can extend toward tick-listing for effective services or action-planning for patient-condition and outcome while managing long-term patient records.

The education sector makes good use of Tableau for comparing management performance. Public-school ratings provide information for facilitating parent choices for their children. Good performing students indicate competence for industry or university entrance. Improvement plans can help school-principals in achieving better practice and future commitment. Student marks from local schools to universities provide a clear picture of ranking and performance during training periods. Finally, a well-prepared Tableau presentation combines all these factors for a clear analysis.

12.1. Business Analytics

Business dashboards are essential monitoring tools in organizations across sectors including Finance, Marketing, Production, and Human Resources. These dashboards rely on real-time data from business information systems such as Enterprise Resource Planning (ERP) and Business Intelligence (BI) systems. A primary advantage of business dashboards is their user-friendly Nature, as they do not demand any specific technical knowledge from users.

Consider a sales dashboard created with Tableau that provides real-time information regarding revenue and product sales across different regions and cities. Such a dashboard enables executives and staff to access data corresponding to their positions within the sales hierarchy. By leveraging filters, user roles can be set to facilitate the prompt retrieval of relevant data. With proper training on dashboard interaction, users can also employ parameters and controls to conduct comparative analyses, such as evaluating actual versus budgeted sales, examining costs versus revenue, and assessing ratios of actual sales in different regions.

12.2. Healthcare Visualization

Tableau facilitates analytical applications in numerous areas within the public and private sectors. This section demonstrates how a sample health-related visualization in Tableau was created. The City of Chicago Data Portal contains datasets for a number of public sector areas including crime, restaurants, licenses, and health. The Chicago Department of Public Health Hepatitis A, B, and C Surveillance section provides datasets for people living with Hepatitis A, B, and C by community area. Three years of data (2012, 2013, and 2014) are available in separate Excel files. Although Dashboard 3 in the example section takes two input files, each of the Hepatitis files can be used as a separate input to produce a meaningful and informative visualization. Although the data currently reflect fewer public health concerns, other areas with data for Hepatitis include the State of Delaware, the Centers for Disease Control, and the National Institute of Health.

12.3. Education Sector Applications

Many education organizations have also benefited from data visualization. An Analysis of Education Systems (AES) Visualized on Multiple Tableau Dashboards accompanied the Global Innovation Index. The dashboards looked at Brazil, Portugal, and the United Kingdom [4-6]. A teacher-dedicated dashboard, Be A Data Detective: Exploring the Education Protection Account, was created to identify where Financial Year 2022–2023 Expenditures originated within the New South Wales Education Protection Account or the global public funds.

A GPA analysis for a particular school across different departments was used to find the departments that lend the highest grades, helping recruiters make better hiring decisions. An interactive map demonstrates the selected enrolment for a university, showing all HEI Colleges, and an analysis reveals the number of laid-off teachers in government schools by different districts. Collectively, these cases reinforce that data visualization can aid all kinds of organizations.

13. Troubleshooting Common Issues

Tableau is an impressive tool for creating advanced charts, but it is not immune to bugs and limitations. For instance, it sometimes ignores column names and inserts its own generic identifiers such as "SUM(AGG(Percent." Agents may encounter data connection errors when attempting to link to Salesforce Reports, Asana, or Jira boards.

Another common challenge arises when the desired data shape does not match Tableau's capabilities. Support staff might be required to clean the data or craft a SQL statement that prepares it adequately, as Tableau generally necessitates data to be in a specific format. These shortcomings do not detract from Tableau's impressive toolset but are important to consider.

13.1. Data Connection Problems

Tableau can connect to many types of data with little to no preparation required. The best advice is: in test mode, connect to each data source you intend to use prior to building the dashboard. This will verify that the data can actually be connected. It will also allow the discovery of alternative methods for connecting to the data, if the original method fails.

When attempting to connect to data, a number of problems can be encountered that prevent a successful connection. These problems are examined here. The common connection problem is that Tableau is unable to reach the data source. For example, a data connection was attempted for an Excel file, but Tableau says the file cannot be found. The probable cause is the file has been moved or renamed.

13.2. Visualization Errors

The previous section explored the different types of data-related errors that one can experience in Tableau. These errors may arise because of data connection issues or data visualization problems. One common occurrence happens when a measure is not aggregated. For example, below is a simple stacked bar chart based on sample Superstore data that reflects the sums of the Sales for each Category and Segment combination. When attempting to drag the Profit field into the Label shelf of the Marks card, Tableau will display the "AGGREGATION REQUIRED" error because, in this case, the pie chart displacement engine in Tableau requires an aggregated field on the Label shelf. This error can be resolved by right-clicking on the Profit field in the Label shelf of the Marks card and choosing the "Measure(Sum)" option. Doing so tells Tableau to aggregate the field, and the error will be removed.

Another common issue is the "INVALID FIELD NAME" error, which can occur if a user manually alters the field names in the data file after connecting to Tableau. An additional data preparation step is needed if field names are changed in the data source. An error may also occur when there is a field with an invalid name. Incorrect field names could be the result of renaming a field in the source data file but not in Tableau. This error is typically found in the Rows or Columns shelves. In the example, the error appears in the Columns shelf because the field name is "Category(y)." This error can be resolved by editing the data sources. The green drop-down arrow at the top left of Tableau's interface will enable quick access to the data source that requires the update.

14. Future Trends in Data Visualization

Future Trends in Data Visualization:

As data visualization matures, technological innovations and sociocultural changes are redefining it. The widespread use of mobile devices and increasingly casual Internet users suggest that dashboards will need to be accessed on a wide variety of devices, especially smartphones. Visualization designers will need to consider sizing, mouse versus finger input, and the access environment when making design decisions [50-51].

The sheer volume of data being collected is also likely to change visualization design. Incorporating new, rapidly changing data sets such as stock market data and sensor output will stress current designs and often produce slower visualizations. In addition, attempts to mine for information in the huge quantity of historical data will require building various query interfaces into visualization systems.

15. Conclusion

Tableau offers straightforward creation of impressive, understandable visualizations from static data swiftly. Engagement and interrogation of data are facilitated through highly interactive dashboards. Users can apply filtering and highlighting actions, zooming in on areas of interest for better insight. Easy publishing and sharing functions introduce interactivity and a “wow” factor to presentations and documents.

Tableau’s power is rooted in these interactive dashboards. Each element functions as a button, directly linked to one or more other elements. This clicking or hovering triggers filtering or highlighting across multiple visualizations. Connecting to a live, constantly updating data source takes a business dashboard to the next impressive level—allowing assignment-monitor managers to select dates or clusters and instantly view related key reference and performance data. Business leaders can examine past, current, or projected performance and initiate timely corrective actions before situations escalate.

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Chapter 4: Looker and Data Modelling: Modern Cloud BI

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1. Introduction to Looker

Non-technical users—product managers, marketing analysts, financial analysts, business owners, and the like—often mock-up dashboards and requests for the analytics team to use Tableau or Power BI. Their data exists in a cloud data warehouse, such as Snowflake, Redshift, or BigQuery. These cloud data warehouses are becoming primary sources of business intelligence (BI). Looker is a third-generation BI tool designed specifically for these cloud data warehouses. Looker provides a simple front-end user interface (UI) for users to explore and visualize data, enabling self-service analytics. However, what distinguishes Looker from other cloud BI engines is its data modelling layer, known as LookML.

Organizations are adopting a single-cloud data warehouse approach to store data captured from operational systems, SaaS subscriptions, and employee-generated content to make business data-driven decisions. As the varied nature of the source systems and business needs does not map clearly to a single normalized data model, dimensional models are created in the cloud data warehouse [1-3]. A dimensional model enables faster execution of analytical use cases but can lead to duplication of data when the sources are not normalized. Continue deformalizing data in a dimensional model is undesirable because of a large number of rarely used managers and their impact on metadata and execution time.

2. Understanding Data Modelling

The term data modelling describes the efforts to create a model of the data in question. Data modelling seeks to define the organization of the data and the relationships among the elements, always with a clear definition of the purpose that the data is required to satisfy.

The importance of these purposes is underlined by the well-known aphorism "form follows function". In an enterprise architecture, the "function" is represented by the defined "business requirements". There is an entire area of enterprise architecture concerned with linking these functions—and, consequently, defining the data—in terms of business strategies that the company wishes to pursue, business processes it needs to run, and business rules it needs to enforce. In a data science process, the different data must be modeled to meet the objectives of the planned analytical activities [2]. Other typical examples are the creation of an integration model that combines the different sources for an unrestricted and rapid exploration of different types of data or the production of a report with the intended results of the analysis.

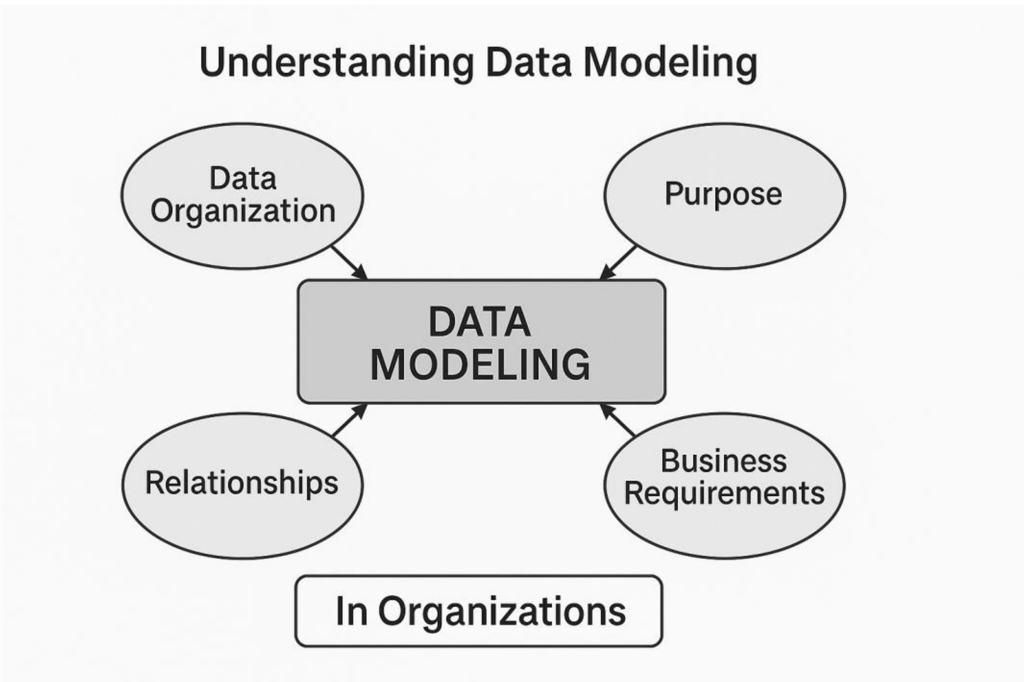

Fig 1. Understanding data modelling

3. The Role of BI in Modern Organizations

Companies across a broad range of industries are trying to harness their data to answer their most important business questions—questions such as “Who are my most profitable customers?” and “Why did sales decline last month?” Business intelligence (BI) tools seek to help these organizations discover relevant insights by simplifying the process of querying, visualizing, and sharing data. BI functionalities extend beyond visualizations; they also include the ability to filter and drill down into an individual visualization or explore related tables. Looker offers all these features. Users can interact with visualizations using filters and drill paths. To explore tables not formally related, they can execute raw SQL queries via the Sql Runner, an SQL query tool built into Looker.

Almost every data source looks different. Some data sources consist of denormalized rows and columns; other data sources contain extremely normalized tables. Similarly, some data sources contain trillions of rows, while others contain only hundreds. Because of these variations, looker allows the modeler to write the modelling code that Looker needs to map to the underlying data. Looker offers a powerful data modelling language called LookML. Users write LookML to specify where Looker can locate data, how various tables are joined, and which fields should be available to business users. When a successful data model is complete, business users can begin browsing and searching for individual fields, joining tables, filtering rows, drilling down, and drilling across without having to learn SQL.

4. Key Features of Looker

Looker is a cloud-native business intelligence (BI) platform with a user-friendly drag-and-drop interface that enables users to perform data exploration and visualization easily. It facilitates data discovery using a modern and intuitive web-based interface while also supporting ad hoc exploration without requiring the user to write SQL queries. The tool provides powerful data modelling capabilities through its proprietary language LookML, allowing users to build reusable models and define key business metrics. Its compatibility with multiple big data platforms and integration with Google Sheets, Google Data Studio, and BigQuery makes it a highly adaptable BI solution [2,4,5].

Looker allows organizations to create interactive dashboards that support real-time collaboration across teams, enabling users to share insights and make data-driven decisions. The platform's cloud-based architecture ensures that large datasets can be analysed efficiently within the data warehouse, reducing the need for data extraction. With robust governance features, Looker offers fine-grained control over users and groups, aligning with an organization's data security and compliance protocols. Users can connect to various supported cloud data sources through the data connections settings in the Looker Admin panel.

4.1. User Interface and Experience

Looker’s web-based interface enables users to create visualizations and dashboards without requiring third-party tools, empowering business users to independently explore data and gain insights. Analysts can design the logical data model using LookML, allowing management to delegate content creation to everyday users.

Looker places data governance at its core, supporting enterprise-grade user roles and permissioning for LookML models, dashboards, and individual queries. This structure ensures consistent and secure data analysis across organizations while the cloud architecture keeps data close to the hosted warehouses, enhancing performance and reducing costs [6-8].

4.2. Data Exploration Capabilities

A single unified source of data is established by the data model, which functions as a semantic layer that translates SQL code into business terms familiar to non-technical users. Looker’s user interface then allows any end user to explore the data, modify queries, drill through rows, filter on parameters, construct new calculations, and visualize the results as bar charts, pie charts, scatter plots, box plots, and more. These visualizations can then be combined into dashboards and scheduled to be delivered via email, Slack, or webhook at regular intervals. Through effective data modelling, organizations can assure the quality and consistency of their data, accelerate its accessibility to stakeholders, and empower data exploration for both technical and non-technical users.

Like most BI tools, Looker is primed for relational databases and enables connections to almost all relational and non-relational databases, data warehouses, and data lakes. A semantically consistent data model can be crafted on top of very large, normalized, and highly relational source tables [9,10]. By contrast, with native querying, the use of enormous, normalized tables is often impractical. However, the use of large tables can negatively impact query performance for a variety of reasons, including complex joins, missing indexes, scan-based queries, and the sheer size of the data set. For projects involving extensive datasets, creating a separate analytical data mart based on a different, denormalized model layer might be more advantageous.

4.3. Integration with Other Tools

Looker further distinguishes itself through its ability to go beyond standard BI and integrate with other business tools. Leveraging different options such as Looker Actions or different API integrations, users can push information directly from their Looker environment. They can also take actions like sending an instant Slack message to an employee who needs to be alerted or create a new lead for their sales team. Other integration possibilities include triggering third-party alerts (PagerDuty, Microsoft Teams) and connecting Looker directly with visualization tools such as Tableau.

By combining data modelling and business intelligence capabilities, Looker has created a fully functional platform. It can be used either as a standalone business intelligence tool, similar to Power BI, or, for users better served by other analysis and data visualization tools, as a pure data modelling and enrichment layer, similar to DBT.

5. Data Modelling Concepts in Looker

A data model can be understood as a formal representation of data within a database, defining the structure and organization of an entire database. Its primary goal is to establish a straightforward method for retrieval, insertion, and modification of data. Modelling data is a highly recommendable practice in data analytics. Looker is a BI tool that differentiates itself through its integration with Data Modelling. Its primary methodology revolves around data modelling, which makes it especially suitable for practitioners who favor this approach.

LookML is Looker’s data modelling language, employed to create views and sets of data. The model code allows definition of dimensions and measures, as well as establishing relationships between different views. Within a Looker project, business users have the capability to request updates to the models using a user-friendly interface, enabling the incorporation of new information as it becomes available. Data modelling is also crucial when dealing with large datasets that necessitate partitioning or sharding. Proper structuring can significantly improve querying speed and prevent server failures.

5.1. LookML Overview

Looker is a cloud-based business intelligence platform that provides data modelling and user-friendly analytics, visualization, and reporting capabilities. It enables users to explore, analyse, and share real-time business analytics easily. A key feature of Looker is LookML, Looker's unique data modelling language. Data modelling is the foundational step of data science that determines the shape of your data and, ultimately, the visualizations you create.

LookML is used to create data models that contain information Looker needs to connect and query the correct data in your data source. LookML names the columns in your database, identifies relationships between different tables, and defines calculations for creating sums, averages, and ratios. The development phase of data modelling involves using LookML to build these models. A properly developed data model lays the groundwork for an intuitive business intelligence experience [11-13]. It allows analysts, product managers, and the broader business to answer questions by exploring rather than simply reporting and delivers a consistent reporting site where every user views the company's data through a single, secure source of truth.

Not all use cases require the same type of data model. Complex use cases require simpler models built upon a robust data platform. Often, data analysts may start exploring data right after it's cleaned without taking a step back to establish a robust foundation that can support their growing needs. This approach may suffice in the very beginning but it will ultimately result in performance issues down the road. Normalized data—small tightly connected tables—is great for operational applications, but it performs terribly for reporting and analytics. When working with large amounts of data, it's important to denormalize data for lookups, dashboarding, and aggregations, creating smaller tables focused on either aggregations or granular data.

5.2. Creating Models

When building BI dashboards in Looker, a model is always required. Models connect and associate database tables with each other and underpin the concepts of Dimensions, Measures, and Filters in the dashboards. In Looker, model files usually have names ending with the Model.ext pattern.

A model is composed of several Explores. Each Explore represents a database table or a set of database views, forming the base table from which service users can select attributes for filtering and plotting within the Explore itself [2,14-17]. In the user interface, these Explores appear as dropdown menus listing Dimensions, Measures, Pivots, and Filters. When a request is executed, Looker combines the selected attributes to construct a valid SQL query. Therefore, Explores represent grouped labels that enable service users to navigate a set of related metrics and attributes within a connected graph.

5.3. Defining Dimensions and Measures

Dimensions and measures are the fundamental building blocks of Looker data models. Defined in the view file, they specify the Fields that Users can select and explore through the graphical User interface. These descriptions correspond to the dimension and measure elements of the LookML syntax (see also section 5.1. Data Modelling Concepts). The Key Features of Looker section introduces the semantics of dimensions and measures in simple natural-language terms nested in the UI hierarchy, followed by a more detailed syntax for advanced use cases.

Dimensions relate to the adjectives of data, providing categories or “granularity” in a query. They correspond conceptually to database columns. Typically, a dimension will display data values taken from a data-column. Such dimensions fall into two types depending on the source column. If the source data is categorical, the dimension is termed a Category or Pivot dimension; if the source data contains dates or times, the dimension acts instead as a Time dimension. Looker supports diverse Time dimensions, recognizing year, quarter, month, week, and day of month as formal types. Each of these natively supports a particular set of time-based visualizations and interactivity in the generated dashboards [9,18-21]. In addition, one can define what is called a Filter dimension to provide a means of filtering down a query.

6. Best Practices for Data Modelling

Business Intelligence (BI) platforms in the cloud enable organizations to leverage advanced analytics for faster, more easily accessible, and better-informed decision-making. Looker's cloud-based BI platform is notable for its data modelling capabilities that create a reusable, scalable, and easily maintainable data structure enabling self-service, governed BI [22,23]. Looker addresses nearly every public cloud analytical data source and delivers an intuitive yet powerful UI, embeddable and integrable analytics, a centralized content management system, and governance control features such as access control and cost allocation. However, its unique combination of a user-friendly BI experience together with a best-practice data model remains the principal user preference.

Data modelling is the process of organizing data into a model that supports efficient access and provides business meaning. Looker defines its data model with dimensions and measures and applies filters and pivots to create queries, processes the results into business contexts, and presents them with visualization options. A symmetric and tabular row-column data model—devised back when storage was the bottleneck—is difficult to either use or maintain in a large-table context. Data modelling best practices normalize Looker's source data primarily to reduce size, then apply aggregation to optimize the query response time on large datasets, thereby minimizing complexity and enhancing maintainability.

6.1. Normalization vs. Denormalization

Advanced data modelling techniques such as the use of derived tables and various levels of data aggregation can impose heavy processing burdens on connected sources. Supporting these advanced modelling techniques requires a data source that can deliver sub-second response times. Without a sufficiently performant connected source, the cumbersome consumption experience associated with inefficient reports reasserts itself. Inefficient reports frustrate a BI strategy and diminish trust in the data. Business users arrive at a place where it sometimes takes less time to prepare the data themselves than to wait for it to be served by the centralized action center. At other times, analysts feel compelled to curb natural elements of data exploration when presented with long or erratic report run times [24-26].

To support advanced modelling techniques and maintain a good level of performance, two important considerations guide optimal data model design. The first consideration is deciding, on a case-by-case basis, which part of the data model should be implemented as a LookML view and which part should be shaped within the connected database via a derived table or persistent derived table. The second consideration is performance tuning the LookML, which includes tweaking query elements, optimizing aggregates, and turning on caching features.

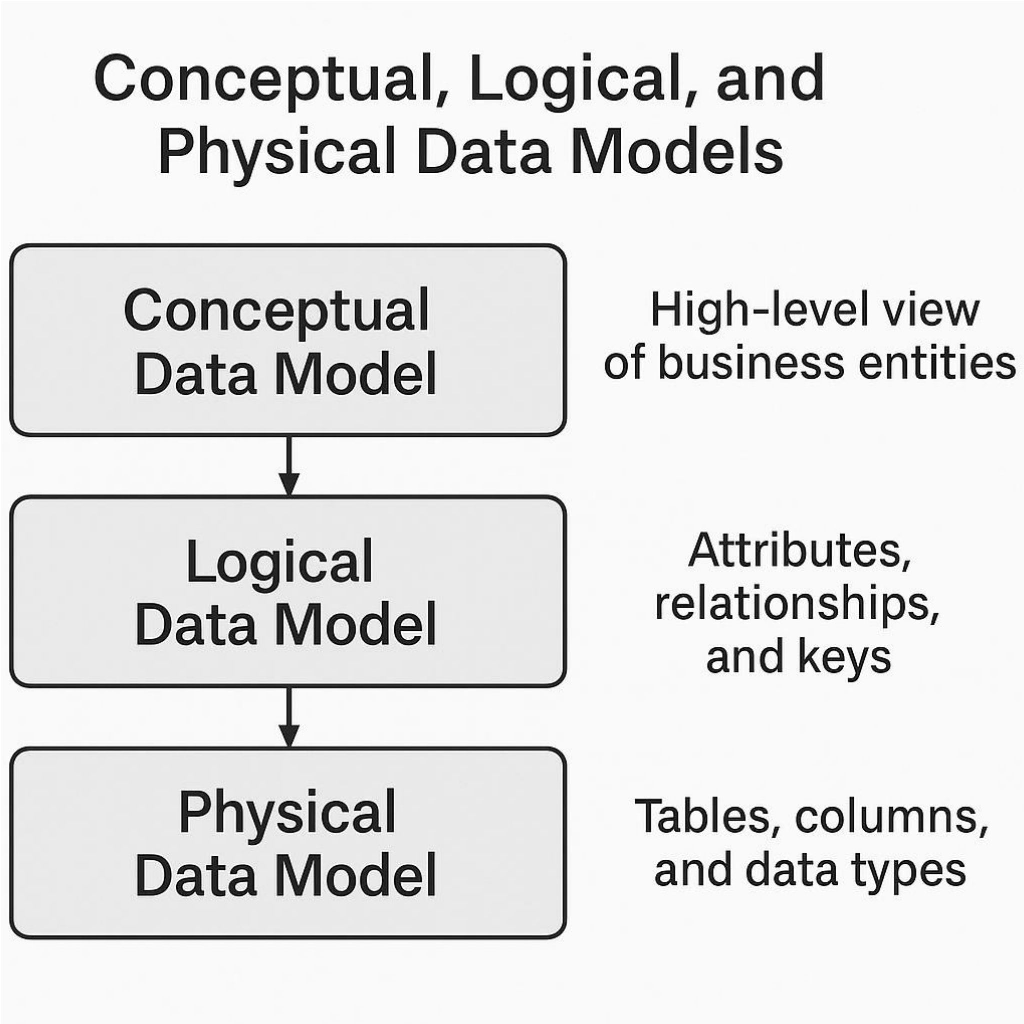

Fig 1. Data modelling

6.2. Handling Large Datasets

Modern organizations collect vast amounts of data. This data needs to be accessible by business users to help make informed decisions. Data models are an abstraction between business users and underlying data sources that play an important role in making data accessible. A data model logically organizes data elements and standardizes how the data elements relate to one another. It also defines rules and semantic meaning of the data.

Complex database schemas that employ normalization and multiple related tables can be difficult for business users and analysts to work with, especially when the data is large. They also require more experience in writing SQL queries that can efficiently handle large data.

7. Connecting Looker to Data Sources

Looker is a modern business intelligence (BI) platform delivered solely through the cloud. Along with being a full cloud BI platform, it can fulfill the data modelling role as well. Conventional BI platforms require building the Data Model first. The designers of Looker can explore the additional Data Modelling concept of the platform and decide whether or not to include it in the solution. Data modelling is the act of exploring and then formalizing the requirements for the structure of some form of data that is to be stored. The output of the act of data modelling is a data model. Organizations across all industries rely on business intelligence (BI) to deliver greater insights for decision-making [27,28].

Looker has a number of features including an interface where business users can perform data discovery and explore large data sets. It also has connectors to many of the key datasource providers, allowing users to access data directly from the source without staging and transformation. Using Looker, organizations can ensure that business users are working with governed, production-grade data without having to rely on business analysts to maintain the data and perform analysis requests. In addition to these native capabilities, Looker also provides well-documented extensions and a flexible API for integration and further customization. It supports standard data sources such as Teradata, BigQuery, and Amazon Redshift. The data-modelling feature enables modelling operations, such as the establishment of relationships, joins, dimensions, and measures in the data sources.

7.1. Supported Data Sources

Looker enables users to connect to various modern cloud data sources, including Amazon Redshift, Apache Presto, Apache Hive, Cloudera Impala, Google BigQuery, Microsoft SQL Server, MySQL, Oracle, and Snowflake. These features facilitate seamless integration with both relational databases and external APIs employed routinely by Looker-powered organizations. The diversity of supported data sources allows Looker to extend capability well beyond individuals' familiarity with particular applications. The procedure for establishing a new connection within the administrative user interface is straightforward: a user with Administrator permissions selects "Connections," then "New Connection," and enters the connection details adhering to the recommended naming convention [19,29-31]. Following the successful creation of the connection, it appears on the connections listing page, with the name serving as a selectable option for visualization development.

7.2. Establishing Connections

Looker supports connections to a variety of cloud data sources that are compatible with the Java Database Connectivity (JDBC) standard. The Business Intelligence (BI) administrator is responsible for setting up these connections, a process that follows the same procedure across different data sources: selecting the data source, specifying the host location or URL, providing connection details, and configuring additional connection options as needed. There is no technical limit on the number of data sources with which Looker can be connected, provided they use the JDBC standard. Another important consideration is the role of data governance in Looker, including the assignment of user permissions and the prevention of breaches. User authentication can be delegated to external Identity Provider (IdP) services such as LDAP, SAML, or Active Directory (AD). In terms of querying capability, Looker offers the option to export SQL query results, visualize data within the interface, or add users to an organization. LookML models can also be leveraged to build dashboards for visualizing data insights.

Looker's LookML data modelling language plays a key role in parsing data for exploration and visualization tools. A data model maps the organization's data structure into a format more familiar and accessible to users who want to explore the data or produce reports. The LookML model file consolidates views and connections, specifying the connections used as query sources for derived tables defined within the views and also assigning sets of views to explore. Models typically define business processes and their related data, while views focus on business entities that make up those processes. Data modelling is central to all BI platforms because the way data is modeled determines the kinds of questions the data can answer and the ease with which the data can be explored to address those questions. Data modelling establishes the relationships among data elements and structures the data into a form that optimizes query performance and the effectiveness of data visualizations.

8. Data Governance in Looker

Looker plays a prominent part in any organization's data governance program. Looker enables a "can or cannot" decision on what data the user can see and may be able to change or delete. The results provide governance—for example, which user can view, change or delete data in a table—and the safeguards needed when the users are finished. Looker supports security, control and compliance in data analytics.

Internal security experts decide which internal users have access to data sets outside the firewall (for example, Amazon Redshift), or which external clients can see a subset of the data without access to the entire database. Organizations store Looker's user roles in the Looker application database. User roles, which allow or deny access, stored within Looker, enable simple and flexible user management. Data governance is essential when scaling up data analytics; this is when an organization uses Looker's features for user permissions.

8.1. User Permissions and Roles

The management of user permissions constitutes a fundamental pillar in ensuring data governance within Looker. Types of user permissions encompass aspects related to access and modification of business information, the Looker interface, and the underlying LookML code [32,33]. These permissions can be assigned either individually or collectively through roles. Roles serve as containers for user permission clusters, facilitating efficient user management and enabling fine control of user-group relations.

Therefore, when designing a Looker instance, it is imperative not only to delineate the business logic and requirements of each dashboard, but also to establish the user architecture, taking into account the necessary rules and security requirements. While Looker allows the creation of permission sets, the process is often laborious and time-consuming, especially during later maintenance. Consequently, it is advisable to define permissions thoroughly at the outset. Ensuring a correct interface configuration is essential for seamless user identification and access to data either in the development environment or the production platform.

8.2. Data Security Measures

Looker supports a robust data governance strategy, making it simple to align data access rules with organizational hierarchy. This ensures individuals can only access and query data that is relevant to their role and permitted jurisdiction.

Looker users, groups, and content all require assigned roles granting specific permissions such as viewing, editing, deleting, and downloading data. Roles help guarantee that users can only access data and content pertinent to their tasks. Pick-and-choose permissions grant access at various levels, including content, content features, administration, authentication, system activity, and user attributes.

9. Visualizing Data with Looker

Looker is a cloud-based business intelligence (BI) platform with an emphasis on data-modelling. Data modelling is the process of structuring data in a reusable way that is easy to explore and use. Modern business intelligence is powered by the flow of data into companies of all kinds. Access to data in a quickly explorable format enables faster and more-informed decision-making, allowing companies to remain competitive. Looker combines its emphasis on data modelling with a user-friendly interface that helps business users visualize data, explore relationships, and identify trends.

Looker supports a wide range of data sources, including the most popular data warehouses and data lakes. Looker's capabilities are by no means limited to visualization [34-36]. LookML—the language that Looker uses for its data modelling—supports derived tables, the aggregation of data, and model optimization. It also serves as the basis for Looker's fine-grained data governance capabilities.

9.1. Creating Dashboards

While Looker is designed to facilitate data exploration and analytics for every business user, it also provides powerful dashboarding capabilities that allow analysts to create polished BI dashboards for all users and stakeholders. Looker dashboards support World server orchestrated scheduled reports and provide extensive features for drill downs and support for dynamically hiding filters based on other filter values.

Activating the Explore section and querying the data offers unlimited possibilities, once a user gets comfortable with dashboarding in Looker. The query results can be pinned to the dashboard. The user can drill down from either the raw SQL-level, or the different aggregation levels, back to the overall data set. Each page takes seconds to generate, since the only SQL actually handled by Looker is one issued by the end user to view the data. Scheduled without database support, the workload simply resides in Looker.

9.2. Using Visualizations Effectively

Business intelligence enables users at all levels of an organization to examine data and uncover new business opportunities. Data is loaded into a visual interface that allows it to be sliced, diced, sorted, grouped, filtered, and searched. Users can employ data visualization techniques such as conditional formatting with colour, highlighting with shapes or text, or graphing as bars, lines, scatter plots, heat maps, etc. Combined, these features help products such as Looker become especially desirable in modern organizations.

Since there are so many ways to present data, the first hurdle is deciding how to visualize information most effectively. Below are dashboard examples for the book Superstore that come with Looker, all of which use the data from table 6.1 (lookml_shopify_orders). The dashboards support different types of users with different business goals; tactical, customer/market, trends, finance, and management. For the best understanding, view the dashboards in the Looker application [37-40].

10. Advanced Data Modelling Techniques

Derived Table LookML allows the definition of derived tables, which are simply tables created by a SQL query. A derived table cannot be referenced by another derived table, and the derived table will have dimensions and measures defined for it. An example of a derived table is the creation of a subset of rows, such as those created by filtering conditions on dates, or the calculation of statistics on groups of rows, such as averages or ranks. The derived table is generated upon running a query using the model in which it is contained.

Although a derived table is created from a table or tables in a connected database, it is not stored there; rather, the results are cached in the Looker application database [41-43]. This means that a database connection that allows writing is required in order to use derived tables. The increased database resources needed to generate derived tables upon execution mean that they should be used only where data cannot be modeled adequately using the other dimensional and measure modelling options.

10.1. Using Derived Tables

An important feature of LookML is using SQL to define derived tables. Similar to database views, these derived tables use SQL queries to define content. But they differ from views in two ways:

• Derived tables are not persistent in the database—they are not stored as views. Rather, their SQL queries are pushed to the database dynamically at runtime. • The SQL query can reference any view in your data model, including derived tables, which allows for very complex logic to be wrapped in simple and readable business definitions.

Looker supports two types of derived tables:

• Persistent Derived Tables (PDTs) are SQL query results materialized in the database as actual tables. Their definition is the associated SQL query. Looker automatically creates and maintains the PDTs using the SQL query provided. • Ephemeral Derived Tables are SQL queries embedded within a larger SQL statement. Instead of materializing the results of the SQL query in a new table, their logic is expanded directly into the SQL statement of the derived table/dimension/measure that references the derived table.

Derived tables are useful for incorporating complex join or aggregation logic into models, as well as performing data transformations that are generally better suited to be made outside the database.

10.2. Implementing Aggregations

Keep the user interface responsive when exploring large datasets by implementing aggregation tables. . Aggregation tables allow the user to drill down into the details, with each level deeper returning more granular data. This approach is analogous to sketches and drill-downs in MicroStrategy, roll-ups in Tableau, and aggregation tables in BigQuery [28,44-47].

The process begins by identifying the most common use cases and defining the queries that support those. Looker generates the SQL for those queries, which can then be fed into a database table, together with the final dimensions required by that use case. Queries that access data at a greater level of detail are subsequently configured to use the aggregated table. This can be achieved by configuring the "sql_always_where" filter that constrains the data to ranges covered by the aggregated data and by reformulating the LookML structure to avoid accessing raw-level data. The aggregated-table approach combines the agility of an interactive drill-down hierarchy with the speed of a high-performing, aggregated database, thereby creating an integrated and highly functional user experience.

11. Performance Optimization in Looker

Data Modelling and Performance in Looker The data model drives both the data and the queries. When looking at performance in Looker, it is important to look at the performance of the data model. For example, a model created with good normalization principles and small tables will result in very different results than a model with denormalized tables. The very nature of the data model dictates the number of joins in the queries and thus the kind of data in the resulting dataset. A dimensional model can handle large datasets very well but there is still room for optimization. Managing datasets with hundreds of millions or even billions of rows require attention to detail to be able to respond query results in seconds or milliseconds. Because the ultimate goal is for the user operating Looker to use Explore in an easy way without thinking about the data model or the size of the Looker model—it is not user-friendly for Looker users to have limitations when using Explore—it is important to be able to create a versatile data model that allows the handling of a large volume of data with high performance.

Query Performance Optimization Large datasets, models with many joins, and queries with a high level of aggregation tend to degrade query performance. It is important to optimize the queries to reduce the overall query time for the user's query to the database. Looker provides options to optimize query performance using derived tables, aggregate awareness, and persistent derived tables. Optimization can be performed at the query level, but some optimization features will duplicate data in the database and will require additional storage Space. These features have a direct impact on query speed but must be carefully modeled and planned.

11.1. Query Optimization Strategies

Looker facilitates query optimization through a two-tiered approach. First, queries should focus on the minimal amount of data necessary for analysis, a concept implemented as Aggregate Awareness. Second, running queries only once minimizes resource utilization, achieved by leveraging Persisted Derived Tables.

Aggregate Awareness optimizes resource consumption by avoiding querying volume tables, which can be resource intensive, and directing traffic to aggregation tables. While the concept is not unique to Looker, the built-in capabilities offering user-friendliness and flexibility position Looker as an excellent choice for business intelligence. Persisted Derived Tables ensures queries are run only once by caching expensive grouping and aggregation operations, significantly enhancing performance [28,44-47].

11.2. Caching and Persistent Derived Tables

Caching is one of the easiest ways to speed up Looker dashboards; it makes queries run faster by reusing the SQL generated by previous queries. The downside is that this only helps when the cards in your dashboard have already been queried recently—the cache expires quickly for rapidly changing filters and data that is fresh-balanced. To learn more about Looker's caching capabilities, refer to the relevant resources.

Persistent Derived Tables (PDTs) allow you to schedule and persist expensive, transformation-heavy queries in the database, rather than regenerating them on every look except when incremental materialization is used. PDTs persist data created by Derived Tables and can be configured for scheduled or triggered rebuilds, serving a similar function as materialized views or indexed views in database systems [48,49]. Looker executes the SQL for a derived table, persists the data in a database table, and replaces the downstream SQL with a SELECT from this cached data table. In some cases, PDTs can be used to extract data from a slow source database, combining and transforming information before loading it into the production database for fast analysis.

12. Case Studies of Looker Implementations

Looker is a cloud-based business intelligence (BI) platform that provides an intuitive interface for business users to create and share reports and dashboards. It also offers robust modelling features that enable expert users to build centralized data models, making it popular in the Business Intelligence and Data Modelling community. Data modelling is a technique used to describe data and its relationships within any domain of interest. It applies certain data model constructs and concepts to represent aspects of the real world in a way that can be stored and processed by a computer.

The following case studies highlight how Modern Cloud BI and Data Modelling with Looker add unique value compared to other BI Platforms:

Business Intelligence enables decision-makers to understand how the business is performing. It allows them to spot trends and identify strengths and weaknesses. Consequently, they are able to make informed, data-driven decisions about every aspect of the business. Looker supports analysis that covers all functions and caters to every level of the organization. It provides an easy-to-use exploration interface, featuring self-service ad hoc analysis and reporting capabilities [3,50-52]. Native integrations with Google BigQuery, Microsoft SQL Server, IBM DB2, and other data sources facilitate rapid data connection. Importantly, Looker supports data modelling to enhance the understanding of relationships within the data.

12.1. Success Stories

Looker enables modern organizations to gain insights quickly through its unique data modelling layer, interactive and user-friendly front-end, and scalable cloud connections. The focus on data modelling can be observed by looking at the companies selected as customer references by the vendor—search for "Looker customer" to find official customer stories published by the vendor. The data model layer is one of the key strengths of Looker and is what sets this business intelligence platform apart from others on the market.

Through the viewpoint of data modelling, it is also interesting to look at consulting companies that focus on Looker implementations and examine the use cases solved together with the lessons learned during different phases of Looker projects. The topic of lessons learned is important because large business intelligence implementation projects often struggle with various challenges and pitfalls. Looker is no different, although the user interface is modern and intuitive. Business intelligence project teams still need to address specific success factors to control the risk of failure or a low adoption level.

12.2. Lessons Learned

Looker adapts to different types of companies and industries. Looker's core concept is data modelling. Looker is a business intelligence solution adapted to the environment of each company. The main newsroom is which of the two — data modelling or looker — is most important; all users have answered the question looker.

Looker analysis centers on Business Intelligence. Looker does data modelling in a BI environment; it goes beyond the concept of any data modelling with dedicated visual functions for the user experience. It links the business intelligence process and the data modelling process in the industry closely. Looker should not be limited to looker itself; instead, it has to be considered in the broader process, including raw data, a data warehouse, looker, dashboards, and finally the BI user.

13. Future Trends in Cloud BI

Looker is a cloud-based business intelligence (BI) platform that enables users to explore, analyse, and share real-time business analytics easily. Looker provides an intuitive, web-based interface to perform analysis tasks, build and share reports and dashboards, and schedule and manage data-driven alerts. It also enables organizations to embed interactive visual analytics features into external applications and provide model-exploration capabilities through the Platform [53-54]. Like other modern BI tools that rely on direct access to data stored in cloud data warehouses, Lakehouses and data lakes, Looker leverages the scalability and power of modern cloud data warehouses to provide real-time analytics. Looker's approach is distinguished by its seamless integration of data modelling, which enables it to address complex scenarios that cannot be met by tools like Google Data Studio. Looker is also recognized by the analyst community as one of the most user-friendly BI tools, creating very positive experiences for analytics consumers and encouraging data-driven decision-making across organizations.

Data modelling is the process of structuring the data stored in a database to meet users' needs and enable analytics. A data model defines how data is organized, related, and accessed through logical constructs that an analytics layer exposes to users. The goal is to organize the data in a way that makes it easy for users to discover and analyse information that supports business decision-making. For business-facing reporting systems, the focus is on the consumption side of BI, supporting the exploration and visualization of information for actionable insights and decisions. Organizations can build their own data models or use external models, such as a data modelling framework provided by a cloud service. Multi-source data models enable analytics that combine data from multiple data sources.

Large datasets can be very large, ranging from several terabytes (TB) to petabytes (PB) of data. The rapidly growing scale and scope of datasets make performance a major concern when using cloud BI tools like Looker. The selected architecture of the data warehouse, the quality of data modelling, and the query engine have a major role in customizing the performance of cloud BI tools and addressing specific analysis requirements.

13.1. Emerging Technologies

Google's Looker BI platform illustrates the growing importance of data modelling to BI vendors and the way they are approaching the field. Organizations can explore large datasets with the richly featured Looker web client or embed visualizations in their own web pages and applications. Visualizations can be shared and scheduled in PDF and Excel files, and the platform runs on the same Google infrastructure as the BigQuery platform. However, Looker's main strengths are its modelling capabilities, and the unification of data-modelling and visual-interaction features in one product. In fact, users focused on data modelling consider Looker to be the best BI product on the market today.

Data modelling covers several important aspects of working with data, outlining the relationships between fact-hubs, measure-specifications and dimensions, together with measures and more complex aggregations. Best practices for data modelling recommend the use of normalized fact and dimension tables, designed to process only the data required for the investigation, rather than the conventional denormalized tables used in reporting [55-56]. Quickly responding to impractically-large datasets by filtering the data often comes at the cost of slower job completion times or query performance. For this reason, many organizations look for analytical tools that support data normalization.

13.2. The Future of Data Analytics

In recent years, numerous organizations have established their reporting infrastructure using Looker. Feedback from users highlights that one of Looker's main distinguishing features is its seamless integration of the business intelligence process with a user-friendly data modelling environment. User comments reveal a preference for Looker's data modelling approach over other platforms.

Analysis of advanced users' comments centres on how Looker implements the data modelling process, reflecting deeper engagement with these capabilities. The discussion also looks ahead to future changes in business intelligence and focuses on collection_analytics.com.

14. Conclusion

Business Intelligence is the practice of transforming data into strategic knowledge and insights that drive better decision-making for the modern enterprise. Looker is a cloud-based business intelligence (BI) platform that enables organizations to derive value from their data and details the important process of data modelling used by Looker to provide user-friendly BI. Looker data models add a semantic layer to mapping the underlying database into user-facing representations, allowing business users to explore and analyse large volumes of data while enforcing data governance.

Data Modelling is the formal process of structuring and organizing data to ensure consistency, accuracy, and efficiency in data management and analysis. Data modelling provides a functional and technical design for how data is stored, linked, accessed, and used. Business Intelligence gathers data from different systems, transforming it into actionable insights presented through reports and dashboards. Looker enables model developers to describe the relationships within their data sets, define business logic, and create reusable structures that enhance efficiency, scalability, and governance.

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Chapter 5: Qlik and Associative Analytics: Exploring Relationships

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1. Introduction to Qlik

Qlik is a leading platform in data analytics that helps uncover complex relationships within massive data volumes. Users can connect data sources with unique relationships and build visualizations—all supported by Qlik's distinctive associative model. This model is often used in conjunction with traditional analytics approaches to find patterns and relationships across diverse data sets.

The Qlik data model is crucial in supporting flexible, associative analytics. Data can be loaded, prepared, transformed, cleansed, and then connected for analysis. Associative analytics enable the discovery of patterns and relationships throughout the connected data, yielding more robust advantages than those attainable with simpler, less-connected models.

2. Understanding Associative Analytics

Data relationships can be extremely complex, spanning numerous tables and linking elements across seemingly unrelated sets of data. These relationships are often not obvious [1]. Associative analytics addresses the challenge of discovering and analyzing thousands of interlinked relationships across vast amounts of data, discovering patterns that can become actionable insights.

Qlik specializes in associative analytics. Its unique foundational data model was developed to support associative exploration across multiple interconnected data tables and sources. The Qlik Data Model chapter explores the architecture of the Qlik data model, its preparation for associative analysis, and the types of connections between data. Associative Data Model compares and contrasts Qlik's approach with other data models and explains why the associative data model is optimized for uncovering relationships. Creating Visualizations in Qlik describes the best practices for visualizing the relationships with Qlik's specialized charts. Finding Relationships in Data focuses on how associative exploration helps identify patterns in data and transform them into insights.

3. The Qlik Data Model

Qlik's associative data model provides an intuitive, flexible way to explore complex relationships among many different aspects of an organization's data. Customers can draw on information stored in many different applications and databases to create new combinations and analyses, limited only by their own imaginations and the whimsy of the business questions they wish to explore.

This section takes a closer look at how Qlik manages this task. It begins by examining data loading, transformation, and connections. Then the associative model is compared with more traditional approaches—both relational and multidimensional—and the advantages of Qlik's approach are summarized.

3.1. Data Loading and Preparation

Qlik's data loading and preparation architecture is designed to capitalize on the strengths of associative analytics. The associative model supports exploration by showing relationships between data, making those relationships easier to see.

To associate data, it is necessary to load the data into a format where it can be linked with other data sets. Associations in data can be created in two ways: during the data load or later as the user explores the data [1,2]. Loading data into Qlik is the first step for meaningful insights and associations. Preparing data for loading requires transforming the data into a user-friendly format.

3.2. Data Connections

Data connections in Qlik's associative model provide the essential links between different data sources, offering a range of features that facilitate diverse data connections and the loading of data into Qlik's in-memory database. These capabilities enable users to combine data from multiple tables, whether simple or complex, and transform it by appending, concatenating, or joining. Qlik supports a variety of customizations and expressions—such as fine-tuning column formatting, specifying filters, grouping, sorting, ranking, and more—providing granular control over the loaded data.

An integral aspect of Qlik's platform is its broad support for data connectors, which include not only the standard Qlik data connectors but also the Qlik Web Connectors and numerous other third-party solutions [3-5]. This extensive connectivity ecosystem ensures that organizations can access and integrate data from a wide spectrum of sources, thereby unlocking the potential for comprehensive analysis. By enabling the efficient loading and transformation of data from diverse origins, Qlik's data connections form the foundation for uncovering relationships and gaining insights within the associative analytics framework.

4. Associative Model vs. Traditional Models

Many data models can connect data sets, and commonly, traditional models like hierarchies and star schemas serve business intelligence needs. However, beyond the specific techniques of business intelligence, there lies a larger challenge: methods to search and connect all types of data, such as text, pictures, videos, and sensor inputs. The limitation of traditional automatic business intelligence data models is that they only support a predefined set of questions—the basic ones. Typical questions include: “Where are we?” (viewing a single value or table), “How did we get here?” (drill-down through a hierarchy related to history-oriented daily sales), “What happened before?” (loading historical data and comparing one period to another), and “Why did it happen?” (running the dashboard through multiple dimensions of products, customers, and region selections).

Qlik’s Associative model supports data discovery, contrasts all related and unrelated values of data, and can later allow loading all types of data [6,7]. The key advantage of this new model is therefore freedom: freedom to explore all answers—regardless of whether questions were predefined or not. The Associative model allows the construction of a discovery capability, answering all questions in days or weeks, not months or quarters. The difference is dramatic. The question, “What happens to our sales if there is a 15 percent discount on Black Friday in store? Zip code 08723, product category—DVD players, in comparison to last year?” is detailed and not a basic answer. It requires a very specific model, and the results would not be correct in traditional BI fashion because the selection of data sets and relationship exploration was not done as part of the initial data model design. In contrast, in the Qlik Associative model, the model is instantly ready.

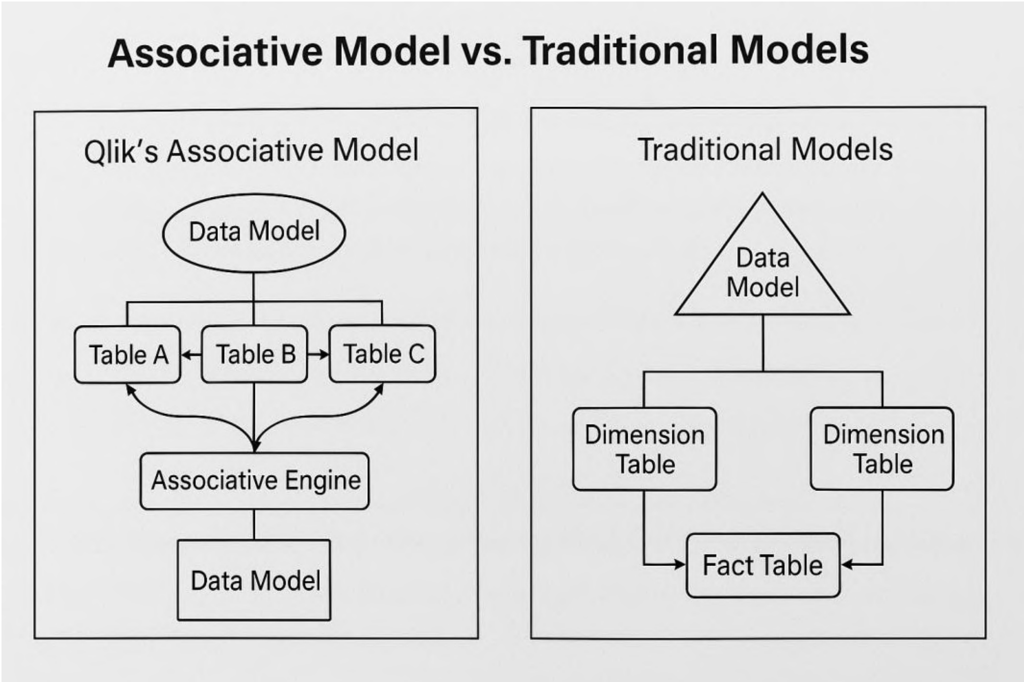

Fig 1. Associative Model vs. Traditional Models

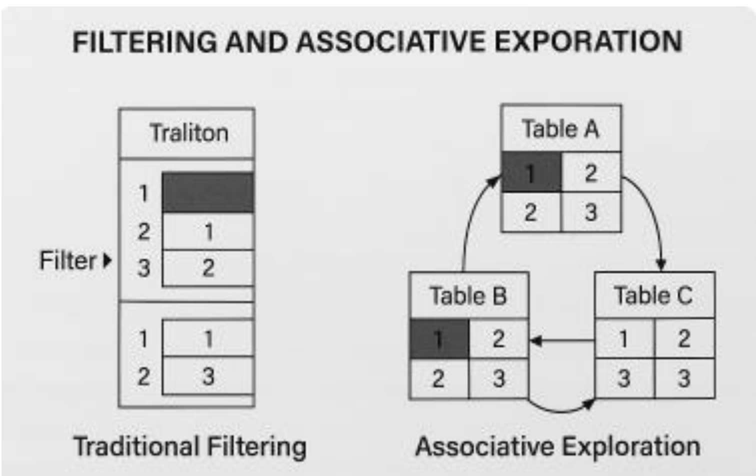

Fig 2. Traditional filtering vs. Associative exploration

4.1. Key Differences

In a relational database, tables ideally contain atomic data, and join fields are carefully chosen to relate tables. In an associative model, the goal is to preserve the data relationships and retain the maximum amount of information for analytical exploration. Relational models work well in transactional applications, but today's interactive data consumption requires an inverted approach. The inverted model uses an associative engine that indexes and links all sources and values. The associative model inverts the traditional approach by loading data into columns rather than rows and mapping all associated values so that relationships and patterns within the data can reveal unexpected insights [2,8-10]. The associative model enables improved data accessibility and better query response.

The flexibility of the associative model allows decision-makers to explore all information, including data and insights that would be undiscoverable in other analytics engines. It reveals all the possible relationships within the data, allowing users to select any field and value across multiple tables, not just a pre-defined join or hierarchy. It's the difference between suggesting queries for users to make and enabling users to ask any question.

4.2. Advantages of Associative Model

Data relationships play a vital role in understanding and interacting with a data set. They help identify patterns, determine trends and outliers, and reduce the complexity of the data set by connecting it with other data for additional context. When relationships are missing, creating a complete picture becomes a challenge and may lead to inaccurate or incomplete conclusions.

The most commonly known data model is the relational model, which relies on queries to connect data. For example, the common SELECT-From-Where syntax of SQL retrieves rows from tables in a database by specifying specific conditions. Instead of relying on queries to explore data, Qlik provides an associative model that reveals relationships that onlookers might not have been aware exist. This model helps answer questions like, "What other information is related to this?" and "Why may this be behaving this way?". The associative model directly addresses the challenge of understanding data relationships by making such findings readily accessible to the user.

5. Creating Visualizations in Qlik

Associative analytics represents a method for exploring relationships within data and linking data points based on their business context. The process involves examining patterns and relationships within data, assisting with business decisions on the next appropriate course of action. Visualizations derived from associative analytics can identify hidden opportunities or risks—for example, determining which customers to target for up-selling or cross-selling, or uncovering reasons for adverse sales trends in particular regions or stores. Qlik provides connectors for business data sources, extracts relevant data, and transforms it to support analysis via a variety of visualizations.

The Qlik data model inherently facilitates associative exploration, allowing users to discover new insights through its interaction-driven interface. The associative data model is the key differentiator of Qlik's Business Intelligence platform when compared with traditional data models used in Oracle and others. With numerous visualization options available, careful selection is necessary to uncover patterns within the data. Qlik's associative analytics go beyond summarizing business performance, enabling the addition of predictive analytics through R and Python integration for forecasting results and outlining next steps. Efficient deployment of Qlik's capabilities requires thoughtful design of the user interface and strategic enhancement of user engagement to ensure that insights are uncovered and acted upon.

5.1. Types of Visualizations

Qlik's associative model enables creation of diverse visualizations that help reveal relationships and answers hidden in data. These include:

- Table. A simple list of rows and columns of information scraped from tables, calculated on the fly from loading scripts, as one dimension or analysis expression against another, or any combination. - List box. A list or drop-down menu of values from a selected table field, allowing analyses and selections. - Bar chart. A horizontal or vertical bar chart. Bars represent either one set of expressions against different values, or different expressions against one value. - Stacked bar chart. A horizontal or vertical bar chart where either all bars are subdivided into overlapping pieces, or, for vertical bars, a bar is subdivided into overlapping pieces and another bar is placed next to it for comparison. - Line chart. A line chart showing one or several analysis expressions over a range of values in one dimension. - Combo chart. Vertical BARs for one or more expressions and a LINE chart for one or more expressions against the same dimensional values. - Pie chart. Pie or doughnut chart comparing values of an expression for all values of one dimension. - Scatter plot. A set of points plotted against two analysis expressions for two axes, with possible bubble sizes and colours indicating two other expressions. - Map. Represents measures against geographical dimensions."Associative Model Revealing Relationships" further explores pattern identification and relationship analysis.

5.2. Best Practices for Visualization

Because of the associative model at its core, all visualizations are linked and Qlik is able to present these links when the user makes selections. This makes it unnecessary to follow best practices with visualizations. However, Qlik is often one of the first data analytics capabilities deployed at a company, so it is important to follow best practices for visualizations to grab the attention of senior leaders. Misused visualizations are skipped over, even if they contain critical information [1,11-12]. Additional can be found in those created by Stephen Few.

Tables are often overlooked since they do not look like typical visualizations, which are circular or rectangular. The truth is that many deliver greater value to users than an actual visualization (chart), especially when combined with sparklines (panels inside a table consisting of a series of marks across a dimension). With Qlik, all visualizations—tables included—are linked through the associative model. Tables can be used as a controller to filter selections or to display detailed data that supports the story told by other featured visualizations.

6. Exploring Data Relationships

Associative analytics enables human linkages among items based on natural relationships such as cause-effect, sequence, proximity, similarity, mirror-image, correspondence, and containment. It uses different intelligence quotient (IQ) levels to identify multiple relationships, delving deeper into the data sources. As a correlational analytics, it correlates the behavior of an item within a group to other business aspects, measuring its influence on the related components for support or explanation. By analyzing relationships, it reveals hidden influencers, controls, dependency, cooperation, and competition—helping users understand why an event occurred, what happened, and what can happen.

Determining when and how relationships among data sources have emerged is essential for contextual evidence as an item moves toward, maintains, or steps away from a specific state [13-15]. Identifying dependencies by examining the hierarchy of events through the behavior patterns of connected items allows for an understanding of mutual interactions that govern overall business behavior.

These insights offer contextual evaluations of items in abnormal or usual situations, facilitating the diagnosis and prediction of causality. Relationships among data sources provide contextual business signals that enhance the precision of diagnostic and predictive alerts.

6.1. Identifying Patterns

The aim of associative exploration is to understand the relationships in the data. By using the relationships in the data, some level of pattern recognition becomes possible. Three primary patterns may be identified—close relations, excluded relations, and isolated relations.

In this context, close relations refer to values that often occur together and have many common elements. Excluded relations—sometimes referred to as "excluded associates"—describe values that are mutually exclusive, never occurring in the same subset. Isolated relations appear very infrequently or have only a very limited connection to other data values in the associative analysis.

6.2. Data Relationships and Insights

Associative analytics is an approach to data analysis that considers the full range of relationships between various data points, elements, and themes within a data set. Identifying these relationships can reveal a complex array of connections, patterns, and dependencies in the data, thereby generating valuable insights [16]. These insights might encompass redundancies, overlaps, causal dynamics, roles and responsibilities, and other interactions. Such broader pivotal questions can be particularly challenging to address using traditional BI tools and data models; in contrast, associative analytics capitalizes on existing linkages within structured, unified data sets.

The goal of data analysis with Qlik is to empower users to explore associations in their data—whether mundane or esoteric—ultimately generating insights that might otherwise remain undiscovered. Achieving this objective hinges on the foundation of the data model: whether the model preserves relationships between most or all data elements in an associative format and allows users to interactively explore these connections in an intuitive, natural, and efficient manner. It then becomes a question of designing and building appropriate visualizations and creating conditions that make associative exploration engaging.

7. Advanced Analytics Features

Advanced analytics capabilities empower users to perform sophisticated analyses beyond traditional descriptive processes. These features enable predictive analytics to discover relationships and make informed forecasts concerning future demand. Predictive analytics involves dissecting historical data to identify patterns that suggest future behaviors or trends [16,17]. It turns descriptive analysis into forecasting, providing data-driven guidance for addressing imminent challenges. Faced with volumes of data, predictive analytics facilitates decision-making by highlighting potential future scenarios.

The analytics features support communication with R and Python, granting unlimited possibilities for visualizing or analyzing Qlik data. Using the integration with R and Python, Qlik developers, data scientists, and analysts can create advanced analytics and machine-learning functions accessed directly from Qlik Sense applications. Integrations are facilitated by plug-ins that communicate with Qlik Engine, responsible for data association and storing the set of selections.

7.1. Predictive Analytics

The combination of garbage in, garbage out and large amounts of data calls for developing ways to automate the analytics process. Automatic detection of trends and patterns allows starting the analysis from a specific result using reverse analytics, starting from a goal and uncovering the possible explanations or causes. The same sort of automation allows detecting anomalies or unusual behaviors. Moving to forward-looking analysis identifies a possible future and evaluates its impact by using predictive scenarios.

At the transition between SIEMENS MindSphere and Qlik Sense, the Momentum app, the Smart Meter app, the Qlik assisted forecasting, and a flow forecast together with the Qlik R and Python advanced analytics integration are some implementations that need to be highlighted as relevant predictive analytics.

7.2. Integration with R and Python

The integration of R and Python into Qlik offers extensive flexibility in leveraging these popular open-source analytics environments. Their vast user bases, extensive commonality in applications, and comprehensive libraries enable enterprises to address diverse use cases and employee skill sets within a common enterprise framework. Selections made through Qlik's associative analytics interface automatically filter applied operations to restrict their scope and focus, furnishing a graphical preview display of the analysis results.

Organizations requiring their predictive analytics component to operate continuously on a schedule, as opposed to on-demand, can choose the "Continuous" mode of operation for the predictive analytics through R or Python [12,18-20]. This option allows scheduling R or Python scripts for regular, repeated executions with minimal overhead. Utilizing the Qlik engine's task scheduling mechanism, the scripts can be run several times per hour. The scheduled execution supports both inline-scored datasets and datasets generated as new tables or inline tables.

8. User Experience and Interaction

User Experience and Interaction are fundamental to the Informatics discipline and every scientific field. Subject/Object relationships and their nuances under dualist/monist metaphysics are at the core of almost all spiritual and philosophical schools. Similarly, an entire branch of social science—psychology—and one of its sub-disciplines—cognitive psychology—study perception as a relationship between a human and an object. The Industry of advertising is based on creating Visual Relationships in an icon, logo, or a commercial [21-23]. Creating visual relationships influences the perceptions of human viewers, who then associate the product with a specific feeling or idea. These relationships connect the viewer's emotion to the image in subconscious, emotional, and spiritual ways, guiding them towards a goal or desired action."The Qlik Data Model" cross-references these preceding statements.

Qlik, as a leading Data and Analytics platform, specializes in Associative Exploration. This can briefly be described as the creation of Numerical, Logical, and Visual Relationships between individual Data-points in a Data Model, while forming Data Sets during analysis. These relationships affect the colours of every chart on a sheet, allowing a user to see associations without changing the selections. Thus, Qlik users can easily identify Patterns across different Charts in a sheet. By exploring Data Relationships, they can extract significant and actionable Insights from seemingly unordered data. The User Experience is based on these Relationships, which are created both by the Data Model and the visualizations built on top of it.

8.1. User Interface Design

User interface design involves all of the elements that are carefully positioned on the screen, including the page layout, number and type of visualizations, and style. Associative Analytics is a journey of exploration. The highly intuitive Qlik associative data model means that the business user will feel comfortable journeying into the data as far as they wish without fear of 'breaking' the structure [24,25].

Support for Selection Made–Alternate Possible Paths Ask What If? Combine Search with Selection and Hierarchies What If–No–What! Cross Highlighting enables the user to select different data points and discover patterns and relationships, helping to uncover interesting insights. An easy, intuitive design keeps users engaged, helping them to focus on drawing conclusions from the data—as opposed to deciding which filter or selections to make next.

8.2. Enhancing User Engagement

The discovery and creation process in Qlik is centered around associative data exploration, which engages users in analyzing data relationships. Qlik's associative model uncovers business insights users haven't yet thought to ask for. Along with the associative data model, advanced analytics capabilities are embedded right into the user experience, providing opportunities for users to interact with predictive analytics, R/Python integration, and explanatory analysis [26-28].

User engagement through data relationships involves identifying and understanding patterns within data. It also includes user interactions that lead to exploring and discovering these relationships, which yields more knowledge and generates new questions.

9. Real-World Applications of Qlik

The real world, where data exists in diverse structures and locations and relationships are far from perfect, is a far cry from "ideal conditions." Yet it is precisely this messy and hybrid data that holds so much value. Qlik's Associative Analytics engine enables businesses to quickly glean insights, combining data preparation and visualization and empowering users to dig into all their data for better answers and more decisive action.Two of the best places to start exploring relationships with Qlik are business intelligence case studies and industry-specific examples.

Business Intelligence Case Studies

Many companies have turned to Qlik's business intelligence and analytics software. Consider how these customers uncovered relationships in their data through Associative Analytics. When a British satellite company wanted to maximize its support efficiency, it found that search wasn't helping engineers identify the right solution – but an associative Qlik dashboard did. A bakery had been tracking the right customer data for years – but only when it was combined in Qlik was the business really able to understand trends. And a snowboarding producer built a flexible, scalable data model that helped it shift with new challenges without requiring hours of manual work.

9.1. Case Studies in Business Intelligence

Business Intelligence (BI) technologies play an important role in converting data into useful and actionable information and helping organizations make better-informed business decisions. Different case studies show how Qlik Sense, by its associative model, business intelligence data visualization, and analytics functionality and features, can be used in organizations to analyse the relationships, patterns, and trends in their data that are crucial for gaining insight [29-31]. Data analytics is also about relationships because many relationships can be hidden in the data, and the development community needs to have the ability to reveal those hidden relationships. Qlik allows the discovery of relevant information regardless of where the data comes from. Associative analytics transforms consumption from passive reading of reports to active interrogating, relies on ODBC, OLE DB, and other standard connections to ingest data from most data sources, supports loading and preparation of data, enables the creation of visualizations, and ensures the model supports exploratory analysis. By identifying patterns in data, predictive analytics can help users define where a business is heading and predict future results. Integration with R and Python enables that kind of predictive analytics.

Other case studies describe how Qlik's associative model can be used in a hypothetical market analysis example that involves both internal and external data. The constraints and limitations that come with BI identified using Qlik are also described [3,32,33]. The discussion then turns to how the BI experience can be improved through better user experience design and examining ways to expose these aspects through the object model to make creating and curating content easier. Other points discussed include empirical evidence demonstrating the ability of Qlik—by its association skills—to evaluate data in very different contexts and find relationships between any records of the tables involved in the analytical process. In more sophisticated analyses, these associations are straightforward blends of diverse data collected or generated on different occasions. The value of these relationships clearly depends on the origin and nature of the collected data. Finally, Qlik's approach to discovery enables a business problem to be identified quickly through exploration, leading to more informed decision-making.

9.2. Industry-Specific Applications

This section provides numerous examples of the use of associative analytics in different sectors involving very different types of problems and questions. Together, they illustrate the broad questions that associative exploration can address and the wide range of real problems it can help organisations solve.

IKEA United Kingdom needed to improve its customer experience while keeping costs under control. The Manchester Excess Management Group – which included representatives from the UK Cheshire Fire Service, Valpack, and Waste Collection companies – faced the challenge of reducing excessive waste collection levels and organised a pilot project in Cheshire to determine whether the existing rules were really necessary. Small-Medium Business (SMB) software provider Wix and a German customer faced the challenge of understanding how their users were interacting with their platform. Bush Heritage Australia, a not-for-profit organisation dedicated to land conservation, had integrated data from various sources, including GIS, to build an effective story-telling tool which provides a richer understanding of conservation management for users and potential donors. McDonald's used Qlik to improve sales performance and competitive advantage in a quickly evolving retail environment. The Public Health Agency of Canada and a Swiss public transport operator had a shared need to improve operational efficiency, increase services, and reduce costs.

10. Future Trends in Analytics

Emerging Technologies Various emerging technologies are shaping the field of analytics and have the potential to enhance the capabilities of Qlik. Artificial intelligence (AI) and machine learning algorithms can be used to automatically generate insights and predictions from Qlik data. Natural language processing (NLP) enables users to interact with Qlik data using conversational queries. Big data technologies facilitate the processing and analysis of large and complex datasets within Qlik [4,34-36]. Augmented analytics integrates advanced analytics techniques, such as predictive modelling and natural language generation, into the analysis process. Cloud computing provides scalable and flexible infrastructure to support Qlik deployments and enable easy access to data.

The Future of Associative Analytics The future of associative analytics lies in its ability to enable individuals, both within and outside organizations, to explore and analyse data quickly and completely. By providing data preparations that connect relevant data and data visualizations that highlight non-anticipated relationships and outliers, associative analytics reduce reliance on intuition and enable deeper data-driven decision-making [37-40]. Qlik is extending its associative analytics capabilities through features such as predictive analytics and integrations with open-source technologies like R and Python. These advancements aim to broaden the scope of business intelligence and transform all decision-making processes by making analytics more accessible and comprehensive.

10.1. Emerging Technologies

The combination of Qlik's capability for associative analytics with advancements in predictive analytics makes the Qlik platform especially attractive to business analysts looking to extract greater insight from their data. While predictive analytics can often be difficult to implement and require a fair amount of expertise, Qlik also provides an intuitive interface that allows analysts to incorporate predictive methods into their analysis in an uncomplicated way [4,41,42].

Many predictive methods and analytics extensions are implemented in the statistical language, R. Because of this, Qlik supports the advanced analytics integration of R through a unique mechanism. Qlik can connect to R, execute predefined scripts at any stage of the analysis process, and utilize the results within the associative model. This is achieved via well-defined functions.

10.2. The Future of Associative Analytics

The core concept underlying associative analytics enables users to introduce a new approach for discovering unforeseen relationships within the data. Future analytics technology will continue in the same direction, facilitating broader, deeper, and more comprehensive exploration of the relationships that are constantly emerging [43-45]. The greater the breadth and depth of analysis, the more crucial the need becomes for business analysts to explore the data interactively without any limitations that conventional query-based analysis places on exploration. For the exploration of ever-broader, bigger, and dynamic data, the model of associative analytics will become both predominant and imperative.

Business analysts are already capable of exploring associations in vast patient populations, association networks in expansive investor cohorts, problems within sales operations across numerous regions, as well as failures across various engine models [9,46-48]. This level of performance represents only an intermediate step in the journey toward continuously-associative analytics. Future customers will delve into the customer, product, and location dimensions that constitute ever-larger markets. Business analysts will also explore patterns and anomalies within broader business networks that incorporate multiple companies, markets, or industries.

11. Challenges and Limitations

As with any analytics platform, the adoption of Qlik can present several challenges and potential limitations, despite the benefits offered through the associative model and other features. Special attention must be given to common challenges during deployment, such as data quality and scalability issues.

The enormous power of Qlik's associative model means that data quality must be very high for analyses to be meaningful. Many companies still rely to some extent on spreadsheets, which generally cannot manage the data cleansing and transformation required for effective analysis. Furthermore, scalability must be addressed at the outset: although the technology itself can handle enormous volumes of data, most businesses have relatively small datasets. Unless the companies are able to scale their own business, Qlik's full capabilities may not be utilized.

11.1. Data Quality Issues

In the light of the preceding discussions, it is vital to note that the Qlik platform is designed only for users, not for developers. Both QlikView and Qlik Sense offer a combination of services, including an engine service for loading and prepping data [49-50]. However, the actual quality of the data loaded is not guaranteed. If the data suffers from poor quality, it will inevitably affect the resulting analysis. As indicated in the chapter "The Qlik Data Model," data quality issues can lead to misleading associations and inaccurate conclusions.

Qlik's data connections facilitate the loading and transformation of information, yet they do not rectify underlying data defects. While the associative model within Qlik excels at identifying relationships between data elements, it inherently cannot compensate for erroneous or inconsistent source data [51,52]. Therefore, robust data governance and cleansing processes remain essential to ensure the integrity and reliability of analyses performed using Qlik systems.

11.2. Scalability Concerns

When organizations seek to leverage the benefits of associative analytics, the practical consideration of scalability must be addressed early in the process [53-56]. Business needs for conducting sophisticated analyses with Qlik are only limited by the quality, completeness, and architecture of the underlying data. However, the promise of drill-down exploratory analytics faces barriers due to data being stored in a centralized data warehouse or spread across multiple distributed sources in heterogeneous formats.

In the age of Big Data, the walls of enterprise data warehouses are being torn down to enable companies to mine diverse data sources for associations and linkages. Technologies such as columnar databases (e.g., Vertica, Sybase IQ, Lotus), in-memory databases, and Hadoop significantly enhance the speed with which large and disparate data sources can be searched for patterns and correlations. This real-time capability is a major advantage not only from the users' standpoint but also from the business perspective. Early customer trend detection, predictive analytics, and operations analysis across large volumes of historical data can now be achieved with timelines that make sense.

12. Best Practices for Implementation

Strategic Planning Certainly it is not the case that the Qlik Associative engine is new and untested. It was released in 1994, and has been further developed ever since, as hardware and software have advanced. Like any Analytics or Business Intelligence (i.e. BI) project, it is important to understand what you are trying to get out of it [57-59]. The strategic planning associated with it is therefore similar to the planning for any other BI project, whether you are moving from spreadsheets, database queries, or dashboards, or from traditional Qlik to Qlik Sense. An essential aspect of the planning is to be clear about who the consumer of the analyses will be. For example, will it be executives requiring fingertip access to data of their own, or prepared analyses of corporate data, or a formalized set of reports, or data scientists seeking to replicate the behaviour of executives to identify patterns and generate forecasts? In particular, in a shift to self-service BI, the Fundamental Insight of Associative Analytics (as introduced in "Understanding Associative Analytics") may be beyond the comprehension of some users or, indeed, may not be necessary. Training and Support The training that Qlik needs is therefore similar to that needed by any other analysis/media self-service project. That is, it requires not just training in the use of the Qlik products (Qlik Sense or QlikView), but also training in handling the specific data that is used. It is clearly important to understand the data itself, and how it is used within the organization. It is equally important to be aware of the potential problems with the data, especially if the data quality is poor or incomplete. By supporting the user and aligning the implementation with the consumer requirements and the data needs, the Qlik Associative Engine can provide a new approach to analytics, enabling users to explore relationships across datasets, without the need to build hierarchies, hierarchically dependent axes/filters, or drill-downs and drillthroughs within the charts.

12.1. Strategic Planning

Strategic planning is a key phase in the successful implementation of Qlik. It requires careful consideration of both business objectives and data needs. Organizations must identify the questions they want answered and the insights they seek before working on the technical details. This might mean designing a streamlined app that uses only the necessary data sources for a particular department or creating a large-scale application that serves multiple teams. The aim is to align Qlik deployments with broader business goals and priorities.

Several factors influence a Qlik implementation plan. The status of existing data infrastructure and the current use of BI tools matter because compatible or complementary solutions can ease integration and reduce training requirements [6,60-62]. The availability of internal resources and skills affects timelines and whether outside consultants might be needed. In many cases, selected Qlik partners offer both strategic advisory services and upfront capabilities development, ensuring that deployments start on the right footing and align with governance and security standards.

12.2. Training and Support

In the early days of BI tools and solutions, these generally used complex scripting and tables in order to connect, relate and associate data from different sources and different tables. It required trained and expert users having good knowledge of data and scripting in order to get solid insights with the correct information. Over the past two decades, data exploration has changed a lot and so have the needs of an organisation and its users. Qlik is constantly evolving, and with its innovations, the use of the tool has moved from expert users to regular business users. The key benefit of the Qlik Associative engine is the ability that it offers to discover hidden insights by digging through data the way business users think. Users want to ask questions and receive answers instantly, without waiting for IT [7,60-63].

Business and Data Analytics (BA/DA) teams can quickly create training notes and videos explaining the business logic of their Qlik Sense reports and dashboards beyond the usual descriptive information. For example, the colour-codes used in charts reflect the selection state, and drill-down and two-way selections on charts and tables are sometimes not obvious to regular business users. Intuitive texts and animation can increase the engagement level of any application.

13. Conclusion

Qlik is among the major platforms in data analytics. Associative analytics is an advanced approach that uncovers hidden relationships between data. The Qlik data model underpins associative exploration by enabling the identification of patterns within data, revealing complex relationships that deliver enhanced insights. In contrast to traditional hierarchical or query-based models, the associative model of data analysis offers users the flexibility to explore data freely without predefined drill paths or restrictive queries. It connects data from diverse sources, presenting it in a manner that lucidly displays how individual data points relate and associate. Visualizing large volumes of data, particularly when sourced from multiple datasets, often generates considerable complexity. While visual analytics excels in demonstrating relationships within a single dataset, it falls short of highlighting insights derived from the interaction of distinct datasets. Associative analytics bridges this gap by connecting different data points and answering questions that linear or hierarchical paths cannot.

The conclusion synthesizes the insights drawn from Qlik’s data model and its association with other areas. Collectively, the presented knowledge provides a launching point for a deeper understanding of associative analytics linked to Qlik. It illuminates the generation of visualizations in Qlik and demonstrates Qlik’s capabilities in uncovering patterns, highlighting relationships within data, and extracting valuable insights. Moreover, it introduces the concepts of predictive analytics and the integration of R and Python within Qlik.

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Chapter 6: Comparison of Business Intelligence Tools

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[1]*Decision Ready Solutions*
[2]*First American Title*

1. Introduction

Business intelligence (BI) tools are applications that analyse an organization's raw data and provide reports, summaries, visualizations, and trends to plan future business activities and enable business managers to make more informed decisions. An examination of BI tools also considers pricing, integration capabilities, scalability, and usability. Aspects such as pricing and usability partly determine the potential risks and obstacles in BI tool adoption [1,2]. The following tabular overview presents a comparison of the most popular BI software, classified and rated according to these criteria. Enterprise-grade BI tools generally support a layered architecture. Integration capabilities include API integration, data source connectivity, connectivity with third-party software, and exporting options for the produced visualizations and reports. Scalability options consider vertical and horizontal scaling, in addition to the choice between cloud or on-premises systems. The analysis focuses on business-users' first contact with a BI tool and therefore gives precedence to interface design and user experience; training and support options are addressed as well.

2. Overview of Business Intelligence Tools

The concept of Business Intelligence (BI) has existed since the 19th century, when Richard Miller Devens wrote about the use of business information in the banking industry. A comprehensive BI software enables the evaluation of corporate performance, the comparison of past data, the identification of areas for improvement, and the detection of new opportunities. It analyses business data and presents the insights through reports, dashboards, and visualizations. BI tools can be implemented in various settings, from small businesses to enterprises with diverse needs. However, a single BI tool may not provide a complete solution. There are numerous tools available on the market that stand out for different reasons, and an overview of the main ones can highlight frequently cited aspects such as pricing, integration, scalability, and usability.

Table 1 presents the Business Intelligence Tools Comparison Matrix, which compares some of the most popular BI tools based on pricing, integration, scalability, and usability criteria. The analysis benefits consultants, developers, and researchers by offering a clear and comprehensive assessment. Pricing models include subscription-based, one-time purchase, and freemium options, each with distinct cost implications [2]. Integration capabilities encompass API support, compatibility with third-party software, and connections to various data sources, all of which determine how well a tool adapts to existing business ecosystems. Scalability examines vertical and horizontal scaling approaches, along with on-premises and cloud computing solutions that accommodate growing data volumes and changing infrastructures. Finally, usability addresses the design and user experience of the interface, as well as the availability of training and support resources, recognizing their critical role in user adoption and effective utilization.

3. Pricing Models

Business Intelligence tools can be divided into various categories according to the pricing: subscription based, one-time purchase and free/freemium. Equally important is the examination of integration, scalability, and usability. A tabular presentation of these four parameters provides a clear overview. The evaluative remits group the available products by use of student ratings and include those that fall into the four highest-scoring categories (Forbes, 2021a). Furthermore, pricing can be evaluated based on a factor analysis of Customers Ease of Use. A first assessment of the new products can be performed according to these four criteria for their Business Model Outlook (Business Model Navigator, 2021). Alignment and integration, scalability, and ease of use are among the most important factors determining the competitiveness of Business Intelligence Products (Forbes, 2021b). These factors can be integrated in a Critical Success Factor framework (CSF). The result is then the BIRSCF framework, which groups the available products by use of high CPO, CSME, and DAP ratings. The four Top Business Intelligence Products (BIPRO), namely Salesforce Platform, Zoho Analytics, QuickSight, and Board, are considered individually in additional cluster heat-maps based on CPO, DAP, CSME, Customer Confidence, Customer Satisfaction, Market Po-pularity, Customers perceive Product Quality, and Support and Training.

3.1. Subscription-Based Pricing

Subscription-based pricing is a payment model that allows users to gain access to a product or service for a specific period. Larger software companies like Salesforce utilize this pricing approach, where customers pay recurring fees to use the product or service [3-5]. This model enables buyers to spread the cost over time, making it more manageable. Organizations often choose the subscription path for cloud-based solutions or software as a service (SaaS), thus avoiding the need for the additional infrastructure typically required with pay-once models. Subscription SaaS applications are usually managed and hosted externally (off-premises). However, the recurring nature of subscriptions can be costly in the long run.

A common example is Apple's iCloud subscription. Many iPhone users are accustomed to purchasing a certain amount of iCloud storage, which can become more expensive over time as needs increase. Some tools on the market incorporate a freemium sales approach, offering limited functionality at no cost to users. This strategy enables start-ups and small companies to attract larger audiences, build a user base, and eventually promote a more comprehensive, subscription-based premium version with enhanced features.

3.2. One-Time Purchase

The One-Time Purchase model involves a fixed cost for a lifetime license, often supplemented by an annual fee for continued support and upgrades. Although this model appears straightforward, associated expenses such as maintenance and additional feature costs can make it less attractive compared to other options. Nevertheless, many legacy BI tools offer one-time purchase licenses.

At first glance, the One-Time Purchase category seems appealing because, except for support and upgrade fees, the bulk of the cost is upfront and easily anticipated. Organizations can acquire the required features without prolonged periodical payments, thus achieving fixed and predictable costs. However, when comparing these tools with subscription-based options available at significantly lower monthly or annual prices—often discounted for initial years—the one-time model may not deliver substantial savings. Additional charges for expanded support or unprovided functionalities further increase the final expenditure.

Performance and integration capabilities within this group also vary considerably.

3.3. Freemium Models

The freemium business intelligence (BI) tool model operates on a "free-forever" basis, generally simple and aimed at small organizations or individual entrepreneurs. The free plan contains only the minimum features and resources necessary to use the platform. An upgrade to the paid plan is necessary for performing advanced operations or increasing the limits of concurrent users, storage space, connectors, etc. There are usually many work restrictions in the free version of BI tools belonging to this group. In Power BI, for example, the free tier allows creation and management of unlimited reports and dashboards, but if the user wants to share it with any other collaborator, a paid plan is required.

Finally, the third pricing category analysed is freemium BI tools, which includes BI solutions offering free plans [2,6]. Most have paid plans too, but the free option hides a clear commercial intention of showing the product while offering services under certain paid subscription plans. Therefore, they should not be confused with the open-source pricing model, in which companies only generate income by offering services like BigDataCloud.

4. Integration Capabilities

API integrations within the integration capabilities of Business Intelligence tools allow a company to synchronize data with other platforms for comprehensive analytics. Although most BI tools provide API access for automation or planned exports, such integrations involving multiple product databases may become costly. Other integration aspects include joint creation and editing features, feed-based collaboration, and connection to other third-party software, such as Slack, G Suite, Salesforce, Facebook Ads, and Twitter.

Data source compatibility also forms an important criterion for BI tool comparison. Most tools connect to flat files like Excel or CSV, cloud databases or web services like Google Analytics or Facebook Ads, and on-premises relational databases such as Microsoft SQL Server, IBM DB2, and Oracle Database. Scalability options provide prominent decision factors for many users, encompassing vertical scaling (scaling up) and horizontal scaling (scaling out). Cloud platforms like Sisense, Qlik, and Looker are dubbed elastic cloud platforms owing to their ability to scale easily and rapidly [7-9].

4.1. API Integrations

An Application Programming Interface (API) serves as a software intermediary that enables distinct applications to communicate and exchange functions or data. In the context of business intelligence tools, API integration refers to the capability of these tools to connect seamlessly with various applications and systems, thereby enhancing their functionality and usability. This integration allows businesses to compile, process, and visualize data in a manner that is coherent with their unique operational workflows and practices.

Pricing structures vary across business intelligence tools, encompassing a subscription-based model with monthly or annual fees, one-time purchase options, or freemium plans offering core features at no cost and premium functionalities at a price. Integration capabilities span API connections, third-party software compatibility, and data source connectivity. Scalability considerations address the methods of vertical and horizontal scaling and the choice between on-premises and cloud-hosted solutions. Usability factors focus on the design and experience of the user interface, alongside the availability of training and support [10]. The accompanying Comparison Matrix presents a succinct overview of pricing structures, integration features, scalability options, and usability attributes for key business intelligence tools.

4.2. Third-Party Software Compatibility

Most BI reporting tools can be integrated with third-party software to meet specialized business needs. However, not all BI platforms support other BI tools. For example, Microsoft Power BI offers seamless integration with various Microsoft services and supports certain third-party plugins, whereas Tableau lacks direct integration with other BI tools.

Integration with additional software also influences BI tool scalability. Vertical scalability entails adding resources to the current server or systems, while horizontal scalability involves adding more servers to the existing network. Depending on whether an organization chooses a cloud or on-premises deployment, three primary options emerge for scaling BI tools: scaling inside the BI tool, scaling through the cloud platform of the BI tool, and scaling outside the BI tool through direct dependencies. Google Data Studio provides auto-scaling via the Google Cloud platform, exemplifying scaling enabled by cloud infrastructure.

4.3. Data Source Connectivity

Business Intelligence tools require integration with a variety of data sources. bi provides connectors with JSON API, Dynamics, and other sources and is compatible with any data source offering Excel Export. Google's product, Data Studio, requires data to reside on Google's platform and does not allow direct API connections to common Google applications such as Google Ads, Google Sheets, and Google Big Query [10,11]. Looker Studio does not support open-source database connections or SQL Server connections. Power BI offers direct API connection with a wide variety of sources but lacks Excel exporting capabilities, like Google Data Studio. ClickUp also offers API integration but shares other limitations with Data Studio, including the lack of a spreadsheet connection and a limited number of third-party connectors.

5. Scalability Options

Scalability remains a pivotal consideration for any business intelligence tool. As the magnitude of data inflow expands, particularly when complex processing is required, vertical scaling can bolster the system's capacity by enhancing hardware components. Alternatively, horizontal scaling distributes the workload across multiple machines, which in turn communicate effectively among themselves to manage the load.

BI tools may operate in cloud environments or as on-premises solutions. Cloud hosting confers advantages such as reduced maintenance demands and heightened operational scalability, enabling resources to be provisioned as needed to accommodate shifts in user demand. Conversely, on-premises hosting may be preferable when organizations require integration with internal systems, lean towards custom development, or maintain perceptions favoring local hosting for security considerations [12-14]. The choice between these models depends on unique institutional constraints and requirements.

5.1. Vertical Scalability

Business Intelligence (BI) enables informed, data-driven decision-making that can fundamentally change the way organizational activities are performed. In addition to helping smaller companies grow and make important decisions, many enterprises employ BI capabilities to sustain their business operations and attain competitive advantages. Currently, a market analysis of BI tools according to pricing, integration, scalability and ease of use is presented. BI tools differ in the range of analytics and the cost model of the company that provides them. Therefore, an overview of popular tools was conducted, comprising a comparison matrix outlining the four criteria mentioned, which appear in these tools, other products on the market and the company s own requirements.

BI tools can be categorized as reporting, data mining, dashboard development, or OLAP. Pricing models include subscription-based, one-time purchase, or freemium. Integration and scalability of selected tools can be evaluated with respect to API availability, compatibility with third-party software, connection to different data sources, the ability to vertically or horizontally scale the tool s architecture, and availability as cloud or on-premises solutions. Usability is further determined by user interface and user experience design, as well as by the availability of training and support. The resulting comparison matrix presents the capabilities of these tools relative to the different criteria.

5.2. Horizontal Scalability

Business Intelligence (BI) tools, collectively referred to as business analytics and reporting tools, have evolved rapidly in recent years. These tools fetch data from various sources, aiding crucial decisions driven by this data. BI tools have transformed traditional static reporting into dynamic, interactive presentations enabling real-time data analysis tailored to individual business needs. They come in various types, including reporting-focused, data discovery and visualization, embedded and portal BI, and self-service BI.

BI tools can be used by organizations and individuals at different levels. The price of most business intelligence tools is based on a monthly subscription fee or a one-time fee. Some also have a freemium model that offers limited capabilities for free or for a limited time. Pricing varies substantially across BI tools, with each designed to meet the needs of specific user categories.

Integration capability refers to the compatibility of the BI tool with other third-party software, ranging from data sources to customer relationship management software or e-mail marketing platforms [3,15-17]. This is one of the main aspects that determine the adaptability of business intelligence tools. API integration is the preferred method for connecting different services and is offered by virtually every BI tool. Scalability capability denotes the ability to manage growing amounts of work or the capacity to be enlarged to accommodate that growth. It relates to the saturation of existing resources considering vertical and horizontal scaling aspects and the flexibility of the BI tool in terms of cloud or on-premises capabilities.

Horizontal scalability increases the capacity of an application by connecting multiple hardware or software entities so that they work as a single logical unit. Data can be distributed among multiple servers in distributed computing, or concurrent processes can be executed across multiple machines in parallel computing to fulfill high throughput and low latency requirements.

5.3. Cloud vs On-Premises Solutions

Both extraction and hosting can be handled by the data cloud provider, enabling small- and medium-sized enterprises to access cloud-based analytic services at a low cost. The capability offered by a particular cloud implementation varies significantly in terms of scalability, data sources integration, data storage and maintenance, system redundancy, functionally, and many other aspects. The choice of an on-premises versus cloud server over a client PC depends on the application requiring protected data storage, intensive data computation or a user-friendly graphical interface.

API integration services enable third-party software applications to connect with an existing system via API so that these applications can utilize existing datasets or developed project outcomes [18-20]. API has been widely adopted by SaaS and cloud service providers because it increases the operational efficiency within the system and enhances the services provided to customers. Scalability refers to the ability of a system to increase or decrease its resources according to current demands. Vertical scaling describes the process of adding resources—for example, upgrading RAM or increasing processor speed—without changing the overall architecture. Horizontal scalability is the capability to add more machines to an existing system or replace them when needed. The rapid growth of SaaS products makes vertical and horizontal scalability more attractive.

6. Usability Features

Assessing the usability of a Business Intelligence tool requires analyzing its user interface, user experience, and the level of training and ongoing support offered by the vendor [21-23]. The ease of use and availability of learning resources play a critical role in determining how quickly users can adopt and proficiently utilize the tool's capabilities.

Poorly designed user interfaces or a lack of customer support may lead to end-user resistance; the tool risks being labeled a "necessary evil" rather than being embraced for its reported benefits. Such dissatisfaction can result in an enterprise investing substantial time and money to implement a tool that ultimately goes underutilized or unused.

6.1. User Interface Design

Business intelligence (BI) tools provide interactive dashboards, visualizations for drilling up/down and using filters, along with self-service reports. Ready connections to multiple data sources eliminate the need for code-free ETL—extract, transform, load—processes. Operations teams must consider usability when evaluating BI tools for their organisation. However, usability is difficult to assess and is often neglected. During the early selection stage, prioritising usability can lead to higher BI productivity.

User interface (UI) and user experience (UX), along with the availability of training and technical support, influence the successful implementation of a BI tool. Enterprises consider usability to reduce the learning curve. Charting and reporting functionalities should enable users to efficiently add visual or informative elements [9,24,25]. The availability of training materials and technical support increases user engagement and study. Table 1 compares these characteristics for several BI tools—DotNetReport, Zoho Reports, Jaspersoft, Dundas BI, and Salesforce Analytics Cloud.

6.2. User Experience

User experience is received in reports and by the users of the reports from Business Intelligence Tools. It is supported through the design of the user interface and the underlying architecture for the user interface. Any complex task requires training of the employees who will use the Business Intelligence Tools. Moreover, user experience is facilitated by the availability of training material and documentation for the tool. Any additional support by experienced BI consultants raises the user experience of the BI Tools. However, when query response takes a relatively long time, the recommendation is to go for an in-memory implementation for BI Tools. An improved query response time will definitely add to user experience. Microsoft Power BI, Tableau, and Qlik Sense are leading contenders when it comes to the user experience.

The convenience of a drag-and-drop-based user interface makes the creation of inventories simple, enticing, and a more favorable customer experience. Such a customized inventory–illustration interface is not only simple to generate and explore but also adaptable across various sectors to enhance the client's business analysis. Visualizations can be created to represent the most regularly used analysis of the KPIs based on client feedback. Appropriate hues, symbols, and the font type of the presentation can be modified based on the brand of the client for greater personalization. Microsoft Power BI, Tableau, and Qlik Sense offer versatile interfaces and allow the creation of drag-and-drop-based inventories.

6.3. Training and Support

The volume of support options offered by business intelligence tools can significantly mitigate potential usability issues. Many vendors provide additional training resources such as videos, webinars, and dedicated trainings for new users, complementing these with professional customer support arrangements [26-28]. Real support options include online forums and help centers that answer common questions. User communities enable users to ask questions and share insights, while chatbots offer AI-powered assistance. Feedback features allow users to report issues and suggest ideas, thereby enhancing the support ecosystem.

Though some sources obtain higher scores for more options, it is important to remember that the mere availability of a support variant is less critical than its quality. Professional support services should have short response times and knowledge levels appropriate for the product's target audience. Online forums need to be receptive to a broad spectrum of questions, ranging from simple queries for novices to complex challenges of advanced users. Dedicated user communities should maintain active engagement without devolving into spam. Pro-active feedback options can lead to actual product-level improvements only when user contributions are actively considered and integrated.

7. Comparison Matrix

Table 1 presents a selection of popular business intelligence (BI) tools and compares their pricing, integration with other business systems, scalability options, and usability [6,29-31]. These features are essential for organizations wishing to build on current investments, minimize disruptions to business performance, gain insights from company data, or reduce the total cost of such systems.

A number of BI tools have been selected as suitable for comparison of the foregoing features. Pricing models among software providers tend to follow three broad categories, namely subscription-based (pay-as-you-go) model, one-time purchase (perpetual license) model, and freemium model. Due to their wide applicability, API (Application Programming Interface) integrations have been selected to represent integration with third-party software, while both vertical and horizontal scaling capabilities are included in scalability. Pay-as-you-go models allow companies to pay only for the resources they use and reduce expenses during periods of low workload demand. In contrast, perpetual licenses usually cost less over time. The free edition of a freemium service, which typically has limited features, will often suffice for many use cases yet also support quick setup.

7.1. Matrix Overview

Where comparison matrices of Business Intelligence tools generally can be grouped by many criteria, the most important considerations often include pricing and licensing models, integration capabilities, scalability options, and overall usability [32,33]. All of the listed tools come from recognized BI providers. Pricing models span subscription-based, one-time purchase, and freemium/limited-use configurations, which can have significant effects on how solution costs form for different organizations and usage scenarios.

Products vary in their support for API integration, third-party and in-house software integration, and in the range and variety of supported data sources, which influence the need for adaptations and extensions. Support for vertical and horizontal scaling, as well as the choice between on-premises installations and cloud solutions, also matters. Consequently, access paths to a set of established criteria for the adaptability of BI Tools are required; these can serve as starting points for an assessment of appropriate scalability solutions [34-36]. Together with user interface, User Experience (UX) concepts, in-product training, and dedicated support options, these aspects heavily shape the user community's ability and willingness to adapt new BI offerings and utilize their additional features beyond traditional reporting and hierarchization.

7.2. Criteria for Comparison

What is a Business Intelligence Tool? Business intelligence (BI) refers to a comprehensive set of computerized solutions employed for the systematic gathering, processing, analysis, and presentation of business information. These solutions empower businesses to make coherent decisions regarding business strategy, operations, and marketing. Essentially, BI amalgamates data mining, visualization, OLAP queries, and business performance management (BPM) [16,37-40]. Several specialized BI tools are available in the market to facilitate intelligent business decisions. The following comparison matrix offers an overview of these tools, focusing on pricing, integration, scalability, and usability.

Pricing. BI tools are typically offered under four pricing models:

- Subscription-based pricing: Customers pay a recurring fee based on the contract. Costs depend on the number of users, features, and support levels. - One-time purchase pricing: A single payment grants permanent software ownership, with a linking service available for integrating with other applications. - Freemium pricing: The tool’s base version is free, with premium features accessible for a fee.

Integration. Integration capabilities of BI dashboards vary considerably. For instance, both Power BI and Tableau support API integration, compatibility with other third-party tools, and connections to diverse data sources. However, only Power BI includes PowerApps and Microsoft Flow app integration [41-43].

Scalability. Scalability options in BI tools differ across providers. Cloud-based services such as Amazon QuickSight and Zoho Analytics offer vertical and horizontal scaling by leveraging the cloud provider's infrastructure. Conversely, Power BI and Tableau are deployable on either cloud or on-premises servers.

Usability. The design of a tool's interface and user experience is paramount for effective business data analysis. Efficient support and training resources further enable users to harness the BI tool's full capabilities. The usability of Business Intelligence tools is fundamental to successful data analysis in a business context.

Business Intelligence Tools Comparison.

7.3. Tool Evaluation

This section highlights a selection of Business Intelligence tools, including Zoho Analytics, Google Data Studio, Oracle BI, and datapine, which exemplify the criteria of pricing, integration, scalability, and usability.

Comparison matrix. The evaluation covers pricing models, levels of integration, scalability options, and user experience. Pricing analysis considers monthly fees prescribed by the subscription model or one-off payments inherent in the perpetual license model. Integration scrutiny interprets API connections with third-party software and connectivity with disparate data sources. Scalability is reviewed through vertical and horizontal approaches and the choice between cloud-based and on-premises solutions. User-friendliness is appraised in terms of the interface, user experience, and the availability of training or support for onboarding.

8. Case Studies

Business Intelligence (BI) tools represent software packages that gather, store, analyse and visualise data for the purpose of making business decisions. They allow organisations to transform data into information and present it in a manner that is easily understood. BI tools can support a range of business activities, including reporting, data sharing, analytical processing and predictive analytics. Key features include scalability, advanced software integration, wide connectivity, and rich visual and interactive components.

BI tools include Tableau, Microsoft Power BI, Qlik Sense, SAP Business Objects, MicroStrategy and TIBCO Spotfire, among others. They are deployed in a wide variety of settings. For example, Microsoft Power BI is used by the National Business Development Agency of Saint Kitts and Nevis to monitor the local economy; Tableau by Amazon for online purchases analysis; and Microsoft Power BI by the University of Portsmouth’s Student Recruitment and Marketing Data Analytics Team for performance visualisation. BI tools are also employed in healthcare, business, telecommunication, retail, manufacturing, financial services, government, finance and logistics [44,45].

8.1. Small Business Implementation

Business intelligence (BI) tools are software solutions that allow business users to collect, record, process, analyse, and visualize data in a way that allows for improved decision making. They typically use data collected from internal databases and external sources to help business users analyse the raw data and discover business performance metrics [22,30,46-48]. Many of the important pricing, integration, scalability, and usability options for popular BI tools are outlined in the following matrix. Pricing options include a subscription model with monthly rates per user, a one-time license cost, or the availability of a free version with limited features. Integration refers to the ability of the tools to be used in an existing BI infrastructure. This involves two major factors: API integration, which enables non-data sources to push data to the BI tool directly, and the ability of the BI tool to connect with third-party software such as Salesforce, Google Analytics, or others. Scalability is about whether the tool can be scaled vertically or horizontally to meet the big data usage needs of an organization, along with whether the BI tool is offered as a cloud solution or is hosted on premises. Usability is a qualitative factor for which a user-friendly interface, a smooth user experience, and the availability of online tutorials and training are all important considerations. A discussion of the tools and services offered for small business implementations follows.

8.2. Enterprise Solutions

Business Intelligence (BI) tools aim to convert raw data into meaningful information for informed decision-making [49-51]. An analytical comparison of BI tools' pricing, integration, scalability, and usability aspects provides guidelines for organizations seeking the right BI solution in today's data-driven environment.

Several BI tools and their key pricing, integration, scalability, and usability parameters form the basis for further consideration:

Hi-Per BI offers subscription-based pricing starting at $160 annually. Its open API enables integration with third-party software, supports connection to multiple data sources, and allows control over user access [52-55]. Scalability is achieved through a cloud platform that supports both vertical and horizontal scaling. A user-friendly interface minimizes the learning curve.

YellowFin BI's service plans cost approximately $50 monthly. An open API facilitates smooth integration, with connections to various data sources. Although scalability features are not explicitly stated, the tool supports both on-premises and cloud deployment options. Its intuitive interface enhances the user experience.

Zoho Analytics follows a freemium model, offering a free plan for up to two users and scaling up to $495 per month for 50 users. The presence or absence of open APIs remains unspecified; however, it connects with multiple data sources. With its SaaS cloud offering, users can adopt tailored plans based on organizational needs. The tool provides useful training resources and comprehensive support.

Power BI Desktop is available free of charge, while the Pro service is priced at $9.99 per user per month. Open APIs support integration, and connections to diverse data sources are available. The cloud platform supports both vertical and horizontal scaling. Microsoft supply extensive training materials and technical support to facilitate user adoption.

IBM Cognos Analytics operates on a subscription-based model, with licensing fees determined by users, servers, and the required set of modules. Closed APIs are currently in place, but the tool supports connections from multiple data sources. Available for both cloud and on-premises deployment, Cognos offers comprehensive training resources and support services.

8.3. Industry-Specific Applications

BI tools support various fields at all company levels. They enhance the production process in manufacturing, monitor patient flow in healthcare, and protect assets in international banking.

Small companies use BI tools to analyse sales trends and customer behaviour through intuitive dashboards [23,56,57]. Large companies rely on BI applications for trend analysis, real-time control, and product suitability assessment. For example, the Deutsche Telekom Group employs an advanced BI-based planning and reporting solution across more than 300 business units worldwide.

9. Future Trends in BI Tools

The integration of artificial intelligence (AI) features into Business Intelligence (BI) tools will likely transform data visualization by streamlining the creation and enhancing the capabilities of visual elements. AI techniques might be employed during various stages—from data collection and cleaning to transformation, modelling, analysis, and visualization—leading to a future where BI tools can describe, explain, predict, and prescribe the information presented. These evolving capabilities will empower users to navigate from summary dashboards to specific data points intuitively, make informed business decisions based on the insights provided, and automatically adjust strategies or plans accordingly.

Future trends in BI services are expected to encompass a broad range of domains, including data warehousing and quality, data visualization, predictive analytics, self-service BI, and cloud BI. Combined with the rapid growth of social media content, the pervasive use of mobile web services, and the popularity of SaaS BI, these trends will further reshape the BI landscape [58-61]. Organizations of diverse sizes, especially those constrained by resources, will gradually transition toward cloud BI services, mirroring the shift already underway for CRM, ERP, and SCM applications. Ultimately, AI is poised to become an integral component of all core BI activities—extending from data warehousing to providing automated or semi-automated descriptions, explanations, predictions, and prescription-oriented insights.

9.1. Artificial Intelligence Integration

Artificial intelligence (AI) is gaining widespread attention in business intelligence (BI) and its related technologies. AI is implemented in various areas of BI, such as data analysis, data integration, data visualization, security, report generation, and many others. Numerous software solutions incorporate different levels of AI features, although the integration capabilities and the degree of AI functionalities vary significantly across the available options.

Integration of AI within BI tools can take multiple forms. Dealers, for instance, may utilize AI to generate recommendations for their clients, such as tailored financing options that align with the company’s criteria and the customers’ financial situations [62-64]. Correspondingly, clients might interact with AI-driven solutions through chatbots that summarize the functionalities of new car models, address inquiries, or propose upgrades. Incorporating AI into BI thus offers considerable potential for supporting companies in a variety of operations, expanding the capabilities of traditional systems.

9.2. Predictive Analytics

Based on actual scouted sources, Business Intelligence is an ascending resource for companies, and when combined with Artificial Intelligence technologies, it further optimizes business performance and industry growth. Predictive analysis can be integrated into the BI system to gain an additional level of insight and discovery. Predictive analytics forecasts on textual data put a burden on traditional BI systems and require the need for artificial intelligence in BI tools. Future scopes can capitalize on this area by refining advanced algorithms that enhance the efficiency of predictions, complemented by detailed data pattern analysis and rule-based learning.

Business Intelligence tools utilize past and current data to support decision-making, employing statistical analysis techniques such as descriptive and predictive analytics. The integration of AI techniques enables the same data to construct intelligent models of the enterprise's environment through cognitive services. This combination delivers comprehensive information about the organization's internal and external factors—capabilities that cannot be achieved by solely dependent Business Intelligence systems. The BI challenges remain adherence to privacy and the cost of AI services as it demands expertise in data science, engineering, and AI technology.

9.3. Enhanced Data Visualization

Data visualization serves as a pivotal function, empowering users to effortlessly identify valuable patterns, trends, discrepancies, connections, and relationships buried within complex datasets. It facilitates intuitive data exploration, comparison, trend analysis, exception detection, and geographical mapping, which are essential for comprehensive evaluations. Effective visualizations clarify business challenges, enhance decision-making quality, amplify persuasive power, and boost user engagement. Charting data trends over time establishes baselines that aid in identifying root causes when deviations occur.

An ideal data visualization platform integrates interactive dashboards, responsive interfaces, and real-time behaviour analysis, all within a unified, visually appealing design that adheres to ergonomic principles and organizational branding [1,65,66]. Support services—encompassing video tutorials, online documentation, and training sessions—further streamline user onboarding and proficiency development. Advanced features such as integrated artificial intelligence and machine learning, automated reporting, and drag-and-drop interfaces equip users to craft meaningful visualizations autonomously. Key platforms delivering these capabilities include Tableau, Zoho Analytics, Microsoft Power BI, SAS Visual Analytics, and Google Data Studio.

10. Challenges in BI Tool Adoption

Business Intelligence (BI) tools are software applications used for the retrieval, analysis, transformation, and reporting of data for business intelligence. These tools aim to allow organizations to make better business decisions by offering historical, current, and predictive views of business operations. For this reason, a comparison and evaluation of various popular BI tools is proposed, focusing on their pricing models, integration capabilities, scalability options, and visual-based usability. A tabular presentation of the comparison reveals that these aspects are critical parameters for selection and adoption.

While BI tools can offer an organization a competitive advantage, many companies cannot leverage them because of high costs and other inhibiting factors. One major obstacle relates to cost; many organizations are unable to afford commercial BI tools. An alternative is cloud-based or on-demand BI services, often called BI as a service. Another commonly reported cause of difficulty is data privacy—internet-based information sharing raises privacy and security concerns that limit the progress of BI applications. Finally, user experience-related issues can also pose challenges to user adoption; thus, user experience studies aim to understand usage patterns and drive future enhancements.

10.1. Cost Barriers

Business Intelligence (BI) tools are software products that process data and generate actionable reports for decision support. Widely used in sectors such as financial services, performance management, sales analysis, and budget planning, BI tools enhance a company's decision-making capabilities. The high cost of advanced BI tools can be prohibitive for small and medium-sized enterprises. The costs—with regard to pricing models, integration capabilities, scalability options, and usability features—affect the wide adoption of BI tools and necessitate an overview and comparison of such aspects [1,65,66].

The Pricing Models Pricing constitutes the major part of the total cost of BI tools for end-users. The common pricing models adopted by most BI vendors are subscription-based, one-time purchase, freemium, and open-source performance. In the subscription-based model, the user usually rents the software for a fixed or metered fee over a specific period and terminates the license on satisfactory completion. In the one-time purchase model, the user acquires the license by paying a fixed price and usually continues the service by paying additional maintenance costs. The freemium model offers a basic edition for free with optional paid features. The open-source model offers free access to source code and enables modification.

10.2. Data Privacy Concerns

Data privacy relates to safeguarding sensitive data from unauthorized access or misuse. With increasing risks, organizations are vigilant about their information and operations. Data privacy laws, such as the European Union's GDPR, mandate security measures, potentially influencing BI tool selection for legal compliance [67-68]. The Canadian Personal Information Protection and Electronic Documents Act (PIPEDA) governs customer information confidentiality, imposing liabilities for breaches. BI tools must therefore provide encryption and role-based access control to satisfy these regulations. The costs associated with a privacy breach, including financial losses, damage to brand reputation, and adverse impacts on key stakeholders, prompt management to consider privacy aspects seriously.

To address employee concerns regarding privacy and BI, educational initiatives, open data-access policies, pilots, and reward systems have been proposed. Ensuring a respectful BI environment that users trust can mitigate fears and resistance. Practitioners recommend collaborative groups that communicate effectively and emphasize that BI should support rather than substitute employees.

10.3. User Resistance

The challenge of user resistance in the implementation of business intelligence tools results from a complex mix of factors, including user interface and experience. Simplicity and intuitiveness of the interface, along with available tutorials and training sessions, play a vital role in accelerating the adoption curve and increasing the usage rate. More straightforward and more user-friendly tools make the users' first approach less painful, lowering the initial resistance level of users in regular use. Well-designed user interfaces also have the potential to open up business intelligence to new user groups within the company besides the actual specialists.

Generally, the business team members are not interested in standard analytics tables and charts. They need charts that make their job easier and be used to getting a clear message without much analysis [69-70]. The concept of instant insight and storytelling with the help of visual charts or infographics can assist in successful business intelligence adoption. Continuous training and awareness about business intelligence tools and techniques help users stay updated.

11. Conclusion

Many cloud business intelligence integration capabilities, pricing models, scalability options, and usability features are examined. A Comparison Matrix further elucidates the distinctions among key tools. Many cloud business intelligence integration capabilities, pricing models, scalability options, and usability features are examined. A Comparison Matrix further elucidates the distinctions among leading tools.

Business intelligence tools provide comprehensive data insights to users and organisations. They can be implemented on-site or accessed via the web through a subscription. Features may include ad hoc reporting, dynamic sampling, multilingual support, schedule organisation, OLAP, spreadsheet integration, and business performance management. Pricing schemes vary from pre-paid plans, one-time payments, and unlimited plans at no cost. Subscription services can address a wide array of business requirements for adaptable corporations.

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Chapter 7: Open-Source Business Intelligence Tools: Metabase, Apache Superset, and Redash

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1. Introduction to Open-Source BI

The term "business intelligence," commonly referred to as BI, comprises the applications and technologies that support financial and business analysis and planning, enabling decision makers to make well-informed decisions. The "open source" designation indicates that these BI tools' underlying programming source code is freely available (without charge) and modifiable by anyone. In general, open-source products provide organizations a cost-effective and customizable method to perform exploratory data analysis; quickly evaluate new tools; support nonprofit, personal, or academic projects; or contribute enhancements to the open-source code base that benefit the larger community.

The focus here is on three open-source BI tools that have consistently been among the best-rated: Metabase, Apache Superset, and Redash. User rankings and reviews for these three tools are consolidated on SpotLight, which conducts an annual review of open-source projects. SpotLight uses its own PeerRank method to evaluate tools based on a combination of quality and quantity of ratings, reviews, and comments from the user community. These three projects consistently place near the top of the ranks for open-source BI, specifically as being interesting for budget-conscious organizations and users, and are therefore worthy of investigation.

2. Overview of Business Intelligence

Business Intelligence (BI) supports the process of making informed decisions and the infrastructure that supports that process. It enables organizations to gather, analyse, and transform data into actionable knowledge. Through BI, decision-makers understand the business environment, past actions, and potential future scenarios. It also identifies actual or potential problems and opportunities[1,2]. BI is critical because of the persistent data growth. It reduces the cost of decisions and improves the quality of decisions. BI comprises a set of processes, methodologies, and technologies that transform raw data into meaningful and useful information, providing insightful knowledge for strategic decision-making.

BI systems provide historical, current, and predictive views of business operations and often focus on business information management. Data warehouses, dashboards, reports, data discovery tools, and cloud data services are types of BI applications. BI Technologies include a wide variety of applications, technologies, and processes. Core technologies encompass data warehousing, business analytics, business performance management, and user interfaces encompassing querying, reporting, Online Analytical Processing (OLAP), statistical analysis, forecasting, and data mining. BI applications address activities such as customer profiling, customer support, sales trends, product profitability, market and competitor analysis, and budgeting and forecasting.

3. Importance of Open Source in BI

Leveraging free and open source software (FOSS) can transform core business operations in various industries and sectors — both private and public, for-profit and non-profit, for commercial and non-commercial use [2]. FOSS enables an organization to evaluate BI software by downloading it, experimenting with it, and determining which features are most important — without the risk of financial loss. Metabase, Apache Superset, and Redash are popular tools within the BI software category. Their combined capabilities rival or exceed those of many proven commercial solutions.

Unlike commercial alternatives that are developed, maintained, and supported by a company that charges for these services, open source software is created, updated, supported, and enhanced by a community of users and advocates. A key benefit of open source software is that it is typically licensed in such a way that it can be scrutinized, modified, and leveraged in a commercial product. Furthermore, organizations that incorporate open source BI tools can capitalize on the existing user base to participate in the ongoing development, troubleshooting, and support. This community-driven approach can help organizations deploy these BI tools more effectively.

4. Metabase: An In-Depth Analysis

Metabase is an open-source business intelligence (BI) product. It uses a simple-to-use and simple-to-install business intelligence environment to pose queries against a data source and visualize the results as dashboards. The dashboards can be set up to display refined visualizations that respond to the initial request made to the data source. Metabase can be connected to numerous data sources including MySQL, Amazon Redshift, and SQLite.

Metabase is supplied with a Docker image. Alternatively, users can download Java files for a manual installation on Windows, Linux, or Mac. After launching Metabase through Docker or Java, the application can be accessed at the http://localhost:3000/ address on the local machine. The initial setup requires creating an administrator account and connecting Metabase to a data source. Subsequent access does not require a username or password unless such options are activated in the Settings [3-5]. The user interface includes an introductory splash page that suggests governance of data, providing of answers, and exploration as the primary functions of the platform.

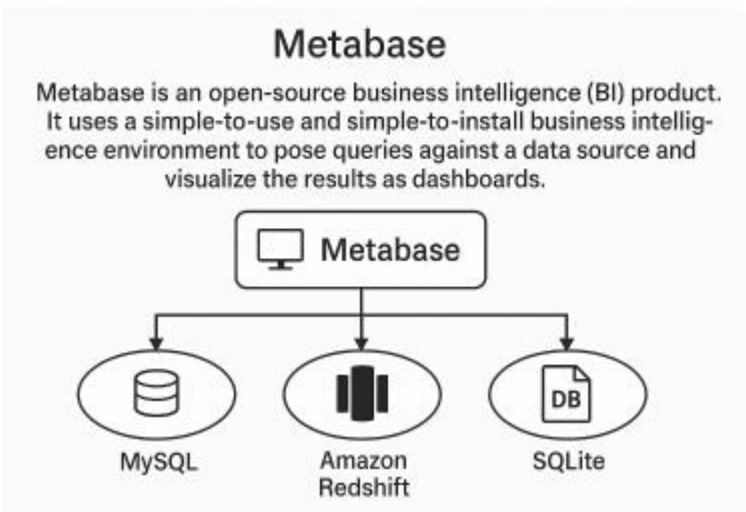

Fig1. Metabase

4.1. Features of Metabase

It is worth first considering the unique features presented Deciding which of the listed three projects should be discussed first. Metabase has the simplest user interface and the easiest installation and configuration [2,6]. As it requires only a simple data source (database) connection, it can be integrated quickly into existing company infrastructure. Therefore, the analysis starts with Metabase, followed by Apache Superset and Redash.

Installation and Configuration

Metabase has a deployment archive that can be extracted and launched across operating systems. If Java is installed, launching the Metabase server is effortless. Alternatively, the application can be launched using Docker. Conveniently, the deployment archive is automatically updated to the latest version. Metabase can also be installed on Windows via its MSI installer, simplifying the database connections process. Holding the mouse over a configuration option usually provides additional tips. After the initial configuration, dashboards appear immediately. Pre-aggregations are present, and the application performs well and responds rapidly. Although there is no separate test environment, it is possible to design complex queries and hide them until needed. Upon completing a query, a user can save it; a dialog then offers options such as embarking on a related question, adjusting alerts, adding items directly to a dashboard, starring, or sharing.

4.2. Installation and Setup

Metabase installation can be achieved through various methods: Docker images, command-line java -jar, AWS Elastic Beanstalk, Heroku, or compiling the source code [7-9]. The Docker container is available at: [Link] Upon the initial run, the system prompts the user to configure the Metabase administrator account and specify the URL for Metabase.

Superset configuration follows comprehensive official documentation (at: [Link] A database is required for Superset metadata, created in MySQL during these tests. After setting up the pre-requirements for a virtual environment, the next step involves installing superset, initializing the database, creating an administrator role and account, defining an encryption key, and finally launching the service. Launching Superset generates logs detailing the URL and login credentials. Additionally, it is necessary to add the connections to databases containing the information for exploitation.

4.3. User Interface and Experience

Metabase boasts a clear, easy-to-use UI that is mentioned in many user reviews as one of the main reasons to choose the platform. The navigation menu clearly lays out the options to ask a question, create dashboards, and browse data, providing a familiar structure.The query builder helps users describe the analysis they want without requiring any knowledge of SQL. If needed, users can switch to raw SQL queries by toggling the graph and notebook icons at the top of the interface [10]. The result set can be explored with the visualization switcher located at the top right of the query result grid. The question builder offers multiple visualization options for understanding the data: Table, Funnel, Map, Number, Pie, Line, Area, Bar, and Scatter. Metabase automatically provides sample data for much of the application interface. For example, the starting page displays Cards containing sample data, and the main interface includes sample dashboards and collections. However, relying on sample data can complicate usability testing.

Apache Superset boasts a modern, polished UI that complements its extensive features. Users can create and save charts using a simple or advanced view. Chart visuals can be used as components on a dashboard, which supports various layouts and contains tabs and headers [10,11]. Additional tools include a SQL Lab for running ad hoc queries, a data-exploration interface, and an extensive machine-learning extension library. The UI is organized with a sidebar structure dedicated to each type of component, such as charts, dashboards, and SQL projects. Security roles and authentication methods offer users the flexibility to secure the dashboards they create. Superset supports user interface translations in multiple languages. For users keen on the latest UI and visualization updates, an ALPHA preview branch is available.

4.4. Data Visualization Capabilities

Visualization is one of the most important features of any BI or Data Analytics tool. Metabase provides many options to visualize data. Many question types are available: Table, time series, bar chart, line chart, scatter plot, pie, number, area, and many more [12-14]. Metabase automatically gives the most suitable chart for the answer. Other icon-based visualization options are also available. Metabase dashboards adjust to the size of the screen it is opened with and users can export questions, dashboard data, and dashboard images.

Apache Superset has a variety of visualizations: Line, Area, Bar, Box plot, Histogram, Pie, Sankey, Data Table, Big Number, Word Cloud, Sunburst, Heatmap, Treemap, Bullet, Calendar Heatmap, Deck.gl.geo, Deck.gl.arc, Deck.gl.Hex, Deck.gl.Grid, Deck.gl.Scatter, Deck.gl-Screengrid, and Time-series. Users can share dashboards with others and also export the data of the chart either as CSV or excel [3,15-17]. Data of the visualizations can be downloaded into CSV/XLS, PNG, and SVG formats. The use of the cross-filter is viable with charts widgets.

4.5. Community and Support

Having an active community of developers–users–technology evangelists is essential to the growth of any open source project. The Metabase community is growing fast. Metabase's Github site has more than 5,800 stars, on Slack there are more than 4,300 members, and the growth rate according to StackShare is 100%. Compared with other open source BI tools, Metabase's community health score is one of the best. This score depends on values such as StackOverflow questions, Discussion forum popularity, Tag popularity, and Slack community engagement, among others [18-20].

On the other hand, the Apache Superset project has more than 40,000 stars on Github, and the related Superset Slack channel has more than 14,000 members. Regarding Redash, there are more than 21,000 stars on Github and over 65,000 Slack members. While Redash was originally part of the AirBnb open source project family, it is currently being maintained by the Databricks team.

5. Apache Superset: A Comprehensive Review

Apache Superset is a powerful business intelligence platform capable of handling data at a petabyte scale. Efficient OLAP engine–druid interaction allows many users to explore billion-row datasets with ease. Its intuitive and interactive interface enables users to visualize and explore data in various ways. Superset offers advanced big data visualization capabilities through an easy-to-use interface without requiring extensive programming knowledge. It supports a range of complex charts and dashboards and integrates seamlessly with Druid for real-time data visualization, augmenting Apache Kylin's capabilities.

Superset runs on Python and uses Flask as the web application framework for the backend [21-23]. The main web server uses Gunicorn, and the SQLAlchemy library supports all its connectors. Superset supports connections to over 30 databases, including MySQL, PostgreSQL, and Oracle.

Superset not only emits simple queries but also modifies them to suit the underlying database by implementing features like pivoting and nesting. Its security model, accessible from a graphical user interface, comprises comprehensive authentication and role-based access control capabilities. Superset supports integration with all major authentication providers, including OpenID, LDAP, OAuth, Google Auth, Remote User Auth, and Database Auth. Installing Superset typically involves creating a Python virtual environment, followed by installation via pip or from source.

5.1. Key Features of Apache Superset

Apache Superset (incubating) is a data exploration and visualization platform designed for modern data teams. Its key features are: easy-to-use no-code visualization creation; support for interactive dashboards; a visualization-building explore view; a SQL editor for running ad hoc queries; lightweight semantic layers for defining metrics; integration with a range of SQL-speaking data sources; role-based access control; and an extensible architecture [9,24,25]. These features combine to provide an enterprise-ready business intelligence solution aimed at creating dashboards that are beautiful, powerful, and interactive.

Superset's simple yet powerful visual design is achieved through a graphical no-code interface that empowers any user, regardless of technical expertise or domain, to uncover hidden insights, regardless of data source or scale. All components can be deployed as Docker containers, while the Superset App Builder tool offers an integrated setup solution that installs and configures all components automatically [26-28]. Connections with standard SQL databases and Apache Iceberg tables, as well as integration with the Hive Metastore, enable browsing of table metadata. The Grafana external authentication plugin extends Superset's security infrastructure, enhancing its enterprise readiness.

5.2. Installation and Configuration

Installation of Apache Superset is straightforward but diverse, supporting deployment natively, via Docker container, or through Kubernetes helm chart. As a lightweight Python Flask app that interfaces with SQLAlchemy, Flask App Builder, and React, Superset is contained in a single container image [6,29-31]. However, this design also means some memory inefficiencies, such as the inclusion of a Selenium driver driver to support screenshotting across all deployments. The following example displays a native installation using Python 3.7+ and the recommended virtual environment. The Docker installation, documented on the Superset Docs website, is the advised path for newcomers.

The configuration process begins with creating a new Superset user in the Admin-User menu to avoid relying on a default administrator. Superset supports various database connectors that easily link backend databases; these are managed from the Sources option in the navigation menu. Upon connecting a source, free-form SQL run against the database can be executed in the SQL Editor [32,33]. With some supporting metadata, it's possible to query specific database tables and their columns to build charts and dashboards. The app's default security settings permit end users to share dashboards and charts within Superset.

5.3. Dashboard Creation and Management

Dashboards offer a broad view, enabling the visualization of multiple metrics in a single interface. Metabase therefore enables the creation of graph collections. As a first step, users define a set of visualisations. These can then be combined arbitrarily. They are arranged on a grid layout spanning the width of the screen in up to 8 segments, while rows are added dynamically [34-36]. The individual elements can be resized freely by mouse drag. The default size of a visualisation is 4 × 4 grid cells. These groupings allow the creation of overviews such as total sales over the past year, sales grouped by region or by individual product.

The completed dashboard will find its way into everyday use – connectivity is central to this use. Metabase supports the automatic sending of dashboards in PDF format on a recurring schedule. This ensures that recipients are continuously kept up to date by e-mail. The sharing of live dashboards is supported through role-based user management. Access to the dashboard can also be provided via an URL token, making it accessible to anyone [16,37-40]. Public access via sharing URL is disabled by default, and administrators can override this setting. The user interface elements described in the Introduction (the sidebar, top bar, etc.) are omitted. For further embedding, an inline frame code snippet is provided.

5.4. Security Features

Combined roles and permissions from Metabase are basic. Users can be assigned groups, and groups can be assigned permissions on dashboards and collections. A collection is a folder or container for dashboards or questions. Staying with folders or containers, Superset has a bit more granularity and refinement. Groups can be restricted to read-only mode for certain databases and can even be prevented from executing queries in SQL Lab on one or more of these databases.

Redash naturally offers a good amount of functionality as well. Readers can create, save, annotate or favorite queries for data exploration, whereas Editors can visualize and schedule query results. Admins have full control over users, groups and data sources.

5.5. Integration with Other Tools

Open Source Business Intelligence (BI) tools such as Metabase, Apache Superset, and Redash offer many features of commercial BI solutions. Crucial for a holistic BI environment is their ability to integrate with other applications for scheduling, reporting, and alerting. Customizable alerts should deliver reports or trigger messages via users' preferred channels [41-43]. Being web-based and accessible from any internet-connected device, these platforms can be easily incorporated into prevailing scheduling systems. Offering Application Programming Interfaces (APIs) enables flexible scheduling through third-party tools and broadens third-party plugin utilization.

Open Source BI tools employ symmetrical approaches to send reports and alerts. Liberator takes its user base as the initial parameter; they configure their message preferences and frequency. Fed must decide on message recipients; the tool supports recipients in scheduling messages. Shared recipients can be maintained in an address book, enabling configuration of messages on their behalf. Redispatcher must specify the recipients for every message, with no address book support. Symmetry crosses the final stage, where the Regional Operator determines message destination details and timing [44,45]. Empower has a set community of recipients; individuals designate their channel preferences and report periods. Messaging preferences lack central knowledge. Once the sender designs the message and selects the audience, Publisher obtains channel details from participants and forwards the communication accordingly.

6. Redash: Features and Functionality

Redash is a collaborative—yet free and open source—tool designed to query data sources, visualize results, and create interactive dashboards. It offers several capabilities analogous to Metabase and Apache Superset. Specifically, the application can be deployed using Docker containers, Virtual Private Servers, or through the Amazon Web Services (AWS) Marketplace. Its interactive user interface provides options to construct, save, and visualize queries, and it also supports filtering and drill-down features.

Redash supports a variety of data sources and types of queries, and each user can work with all of their available data sources [22,30,46-48]. The querying process includes a code editor equipped with tools for writing and testing each query. Once created, users can save queries and share the resulting visualizations with other members. Visualizations in Redash are flexible, enabling the creation of different charts based on specific needs. Complex dashboards can be organized by assembling a set of saved queries, thereby providing a comprehensive view of an entity.

6.1. Core Features of Redash

Redash emerged from the tech community as an open source competitor to paid business intelligence (BI) tools. It connects dozens of data sources allowing users to create queries through a browser-based interface. The results of these queries can then be shared with others, allowing organizations to make data-driven decisions. These elements illustrate the foundational motives behind any modern BI platform: democratizing access and visibility to relevant data. Redash has been developed and maintained by a dedicated group of open source contributors since its inception and was acquired by Databricks in 2020 [49-51].

In addition to creating starting points of new analysis, Redash also provides a range of ways to view and monitor query results. Charts and graphs—which are easily created within the interface—can be shared with others as part of a dashboard, allowing for monitoring trends of the data and helpful visualizations. Query results can be returned at regular intervals and shared with individuals or teams by pushing them out into email or Slack. Combined with role-based permissions, this makes for a particularly flexible alerting system tailored to the needs of the users and organization.

6.2. Setup and Configuration

Redash offers a hosted service on the official website, allowing users to sign up and gain access to many data sources immediately. However, to connect to data sources not supported by the hosted service or for additional control and customization, the tool must be self-hosted. Redash is written in Python and uses React. Deployment is relatively straightforward, with an officially supported Docker Compose configuration that can be used in Docker or Podman to deploy Redash and all required components. The necessary environment variables can be set in a file, and additional files such as certificates can be mounted in the container [52-55]. The port 5000 is exposed and can be used directly or routed through a Web Server Proxy like Nginx for SSL support and production use.

When the instance is freshly set up, Redash displays a landing page and allows connections to various supported data sources. Users can write queries either in the web page using editor shortcuts or through the visual query editor. A wide variety of visualizations are available, enabling users to create insightful dashboards and reports. Dashboards are shareable via share links with different security levels—password-protected, public, or accessible only for logged-in users. Dashboards have full support for embedded applications and can be easily embedded using iframes.

6.3. Querying Data Sources

NoSQL databases, although supported, are not recommended because queries require manual coding in their respective query languages. Supported NoSQL databases include Elasticsearch, Google BigQuery, MongoDB, Apache Druid, Snowflake, Glu, and Apache Pinot.

Query editors make sense only if the queried database is structured and suitable for creating visual representations [23,56,57]. In nursing business intelligence, unstructured or complex data can be challenging to extract and analyse, so high-level visual editors can simplify the selection, filtering, and sorting of structured data.

6.4. Visualizations and Dashboards

Users can share the link to a dashboard or make it a home dashboard, or download it as a file. For each visualization on the dashboard, users can inspect the underlying data, change the visualization type, or dive deeper into the query in the editor [58-61]. The homepage shows a collection of assets, including recently accessed dashboards, saved queries, and users.

Apache Superset supports role-based access control with native authentication or any authentication supported by Flask AppBuilder, such as OpenID, LDAP, OAuth, or remote user authentication. Flask AppBuilder also supports granular control of permissions, roles, and view menus.

6.5. User Collaboration Tools

Logical collaboration and easy sharing of insights and analysis results are definitely integral components of any BI tool, so all 3 tools provide such features [62-64]. Metabase analyses and dashboards can be built via a simple interface that nontechnical users can understand, making it easier to communicate the final results through the sharing option. As a result, other users who receive the natural language questions and dashboards are certainly not required to have access to the Metabase core product, especially to the data. The view function of Metabase further allows other analysts or users to explore the query, change the data aggregations, filter the data, and use it as the source for another question, as long as the question creator has granted the permission to do so.

Metabase facilitates team collaboration by sharing data insights through public and private links, embedding dashboards in public websites, and organizing dashboard collections. Restricted share links offer precise authorization control to ensure secure data distribution. Additionally, Metabase features Slack integration to enable users to receive real-time alerts on specific metrics and a subscription functionality to schedule regular email updates. Apache Superset is also efficient for team collaboration; its charts and dashboards can be set as public or private and shared with specific users or groups. Organizations can use the native roles and permissions authentication system or easily integrate Superset with an existing authentication provider over OpenID Connect, LDAP, OAuth, REMOTE_USER, or database. The embedding capabilities enhance data distribution. Redash provides collaboration by allowing users to create personalized dashboards with elements from any query. Users can schedule email reports for their dashboards and subscribe to Slack notifications for query alerts.

7. Comparative Analysis of Metabase, Apache Superset, and Redash

An exploration of Metabase, Apache Superset, and Redash reveals that all three form a popular class of open source business intelligence and analytics software. Metabase is distinguished by its automated business analytics and dashboarding support, Apache Superset is a modern data exploration and visualization platform designed for scalability, and Redash is a lightweight web-based platform for querying and visualizing data. Each has a vibrant community and backing from active companies, with offerings available in SaaS and self-hosted forms.

The arrival of the age of data has propelled business intelligence into the spotlight [1,65,66]. Organizations collect, store, and process enormous quantities of data from a multitude of internal and external sources. These large datasets need to be reduced to actionable information, ideas, and reports, which can then inform strategic business decisions. To satisfy increasing needs and growing budgets, a corresponding number of business intelligence solutions have emerged and continue to evolve. For users who do not want to be locked into proprietary platforms, Metabase, Apache Superset, and Redash form a powerful cluster of open-source alternatives.

7.1. Feature Comparison

Metabase, Apache Superset, and Redash represent a subset of open-source business intelligence tools. Metabase stands out for enabling ad hoc and deep analysis through a simple interface designed to facilitate exploration by all business users, offers detailed analysis capabilities beyond its simplicity, and includes scheduling and sharing of updates. Apache Superset targets professional data engineers and data scientists interested in creating comprehensive dashboards. Redash caters to a wide audience by combining ease of launch, scalability, stability, and support for diverse visualization types.

The appeal and growing interest in open source BI stem from the cost-free nature of the software, the large community of developers refining code and resolving errors, and the ability to tailor the tool to specific business needs. Metabase, Apache Superset, and Redash collectively exemplify these characteristics, and their common features warrant closer examination. Open source business intelligence, often abbreviated as open source BI, describes software packages that analyse and visualize data contained within an organization and are distributed under an open source licence or released as free software [67-70]. The term generally excludes open data sources provided by companies and governments.

7.2. Performance Evaluation

Business intelligence (BI) enables organizations to collect, store, analyse, and present data for decision-making. The review evaluates the performance of three BI tools—Metabase, Apache Superset, and Redash—using testing tools like JMeter and browser developer tools to measure response times for various queries and dashboards. The tests are conducted in virtualized environments, analyzing CPU, memory, and network demand.

Performance tests comprise two categories: simple and complex queries executed via the UX interface, and dashboard loading tests. Although these evaluations provide useful benchmarks, real-world implementation times typically depend on query complexity, volume, and infrastructure provisioning.

7.3. User Experience Comparison

Business-intelligence tools have come into the spotlight because of their relevance during the COVID-19 pandemic, when all companies—all industries—need to use data to guide their decisions and deal with problems caused by the pandemic [71-73]. Because there are many Business Intelligence platforms, data users must select the best platform for their needs. There are many options such as: Metabase, Apache Superset, and Redash.

Open-source business-intelligence tools allow companies to establish a quicker business-intelligence process with great visualization. Users must master the SQL language in order to run one of these features. However, Metabase accepts answers without SQL language; it can use language-mode functions.

7.4. Community and Documentation

Quality documentation and a helpful community are critical for any contemporary open source business intelligence platform, especially for getting new users quickly up to speed and for overcoming advanced difficulties. Each platform integrates a broad spectrum of documentation resources, including detailed user manuals, installation guides, feature tutorials, and troubleshooting articles. Metabase's documentation is structured around key concepts and guides for the most common use cases, and the dedicated "Ask the Community" forum provides a productive space for inquiries and discussions. Superset's documentation covers installation, feature walkthroughs, architecture, development, and security. The Superset Google Groups mailing list and the #superset channel in the Apache Slack workspace enable real-time communication and support. Redash's documentation includes information on community edition deployment and configuration, along with guidance for hosted Redash services. Communication channels encompass a forum, mailing list, chat platform, and support website, fostering a vibrant user network [35-74-76]. Despite these provisions, all three communities recognize the value of additional tutorials, videos, and example queries and dashboards, especially those contributed by users with domain-specific expertise and well-documented subqueries.

Between Metabase, Superset, and Redash, the available documentation resources cover virtually every scenario, and dedicated Slack channels and community hubs generate rapid responses to challenging queries. Additional contributions of well-documented queries, dashboards, tutorials, and use case videos would enhance the knowledge bases and facilitate quicker onboarding and more effective use. Such additions, particularly those offering domain-specific expertise and thoroughly explained subqueries, would strengthen these evolving ecosystems.

8. Use Cases for Open-Source BI Tools

Open-source business intelligence (BI) tools enrich operations across industries. Drivers of adoption include cost control via zero license fees, swift project initiation and realization, smooth scalability for growing data, high feature parity with commercial tools, and robust support from enterprise software providers. Metabase and Redash typify the easy-to-handle category; Apache Superset aligns with the

9. Challenges of Implementing Open Source BI

The use of open source business intelligence (BI) tools presents significant advantages for organizations seeking to make effective use of their data. By closely examining the challenges associated with the implementation and operation of Metabase, Apache Superset, and Redash, it is possible to obtain a clear picture of what an organization can expect when opting to deploy one of these tools in-house. These obstacles encompass a range of factors related to installation, administration, user roles and permissions, visualizations, geospatial capabilities, public sharing, embedded analytics, willingess to contribute, and community support [52,77-79].

Installing an open source tool may appear relatively straightforward to a software developer, yet many individuals within business units lack the necessary skills to complete the process unaided. Satisfying specific business requirements can prove difficult when organizations are heavily dependent on hosting providers or managed, trusted partners. An internal open source implementation demands alignment between the involved community and an organization's environment and policies. Despite accessibility from a financial perspective, open source tools require sufficient human resources for upkeep and development. Organizations that aspire to benefit from the freedom and flexibility of open source software will ultimately either contribute themselves or pay a company to do so.

10. Future Trends in Open Source BI

Three open source BI tools—Metabase, Apache Superset, and Redash—have substantial user communities. Combining the advantages of these and other open source BI tools creates checkpoints for commercial products. At the same time, new ways to broaden their functionalities and refine their experiences shape the self-service trend of business intelligence.

Organizational data volume continues to grow, encouraging the integration of machine learning and AI into the open-source BI arena. Large data repositories require new facilities that allow effective analysis on large-scale data at an affordable cost. Soon, several trends identified in the commercial business-intelligence landscape will become the hotspots of development in the open source BI landscape. The integration of artificial intelligence, the investigation of organizational data volume, and the promotion of collaboration among users are three identified future trends.

11. Best Practices for Choosing a BI Tool

Business Intelligence (BI) systems revolve around building various types of reports—simple table reports, pivot tables, graphical reports, and dashboards—in which the dashboard is at the heart. Starting from a dashboard, other reports also need to be created. On the other hand, BI systems need to support seamless access to multiple data sources, ranging from SQL databases, NoSQL sources, Google Analytics, Hadoop, Salesforce, Teradata, and other systems, regardless of data owning organizations, including metrics, transactions, account, customer behavioural, and product usage data within a company.

A BI tool must support various ways to build dashboards and reports with minimal effort, such as lookup operations, filters, grouping, SQL query generation, writing SQL queries, and importing reports uploaded from Excel. There are two ways to choose an open source BI tool: (1) identifying the best open source BI tool through a meta-analysis based on online BI research articles, requirements, and evaluation reports of open source BI tools as reference; or (2) selecting the best open source BI tool by considering the unique requirements of the current BI system development. The latter approach is discussed in more detail in relation to three popular open source BI tools: Metabase, Apache Superset, and Redash.

12. Case Studies of Successful Implementations

Open source business intelligence plays an essential role in growing organizations and expanding businesses. Dashboarding self-service tools such as Superset, Metabase, and Redash enable companies across every industry to deliver insights in a timely fashion. Metabase is one of the most widely used data analytics and visualization tools. Metabase offers a powerful yet easy-to-use interface. It connects with most popular databases and requires zero knowledge of SQL. As an open-source tool, it supports a wide community of users and offers a rich ecosystem of product extensions and add-ons. Superset is a modern, enterprise-ready business intelligence web application. It offers a simple interface that allows users to explore and visualize their data, quickly creating and sharing interactive dashboards. It can replace or augment proprietary business intelligence tools for many people. It offers rich support for visualizing time series, geospatial charts, and more. Administrators can monitor the performance of queries running against all the connected data sources to optimize the dashboards and visualize the usage.

When selecting a business intelligence and visualization tool for an organization, it must provide an excellent selection of visualizations. It has to encompass the ability to execute raw queries and compose visualizations by seamlessly connecting with the database [78-80]. It supports a subset of commonly used databases, connects with custom functions, allows different authentication mechanisms, and offers advanced sharing or collaboration functions. Once visualization is complete, fast queries with a CSV report and scheduled alerting functions are now part of the decision-making processes. Redash is an open-source web application for querying databases, creating visualizations, and sharing dashboards. The easiest way to describe it is a user interface for data. Redash supports native analytics and data visualization in a similar way to Tableau or Looker. It is a PoC tool for building internal visualizations and dashboards. It supports scheduled queries, a query editor, interactive dashboards, and many other features.

13. Conclusion

Open source business intelligence tools Metabase, Apache Superset, and Redash have introduced powerful, flexible capabilities at a fraction of the price of traditional commercial platforms. They incorporate visual dashboards, charts, and graphs — elements characteristic of most modern BI tools. Combining cloud hosting with open source licensing has supported scalable analytics solutions serving thousands of users across organizations. Driven by active communities, these platforms continue to deliver new features, establish advanced scalability, and attract users wanting straightforward yet robust insights. Providing accessible BI tools for a broad audience enables the data-driven culture, ethos, and rigor that are increasingly important for organizations in all sectors.

Business intelligence (BI) altogether represents a large, growing industry of software vendors, with recent forecasts suggesting add-on services could compose a $35 billion annual market. Most current tool offerings optimize presentation by converting query outputs into visual representations designed to inform management or guide analysis. Business intelligence, also known as global performance indicators, includes internal transaction and project management data as well as external market, industry, or price data. Coherent presentation of select indicator groups can provide a full view of overall progress toward strategic objectives. Typically, a handful of key indicators fulfilling these criteria come to dominate the graphical user interface.

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Chapter 8: Exploring Practical Applications of Business Intelligence in Various Sectors

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1. Introduction

Business intelligence (BI) refers to the use of techniques and tools to transform business data into meaningful information for making effective business decisions. BI serves as a bridge between raw data and decision support systems, with applications spanning retail, healthcare, financial services, telecommunications, and manufacturing. The rapid growth in data generated by operational and transactional systems has accelerated the development and adoption of advanced BI techniques aimed at efficient data handling and information extraction. Moreover, in an era characterized by highly competitive and turbulent market conditions, organizations face significant challenges in extracting valuable information to provide outstanding products and services. Business Intelligence emerged to address these challenges, aiding in unlocking the potential of organizational data for informed decision-making.

Despite its relatively recent introduction, BI has become an important concern for many businesses. It encompasses virtually all business money and supports all aspects of internal business processes and functions. The increasing need for BI stems from the rapid exponential growth toward e-commerce, which generates a huge amount of data related to products, customers, order labels, payment processes, and delivery. The tremendous growth rate of unmanaged and unstructured data—commonly referred to as "dark data"—within corporate systems is pushing organizations to leverage the power of BI and data warehouse solutions to enhance business analysis and customer relationships.

2. Overview of Business Intelligence

The term business intelligence (BI) most commonly refers to tools and processes used to gather, provide access to, and analyze data and information about company operations [1-3]. The goal is to support better business decision making. Any fact-based support for business decision-making can be considered business intelligence. Companies around the world invest in business intelligence to help them compete more effectively, better satisfy customers, and boost profitability. There is no single, precise, and universally accepted definition of business intelligence, and so the list of processes and applications enabled by BI varies from one source to another. However, it is safe to say that BI was, at least until recently, largely about managing enterprise information, with a focus on extracting patterns and trends from large sets of data. Combined with the ability to efficiently locate information inside an enterprise, the ability to identify past patterns and trends enables business users to understand and respond faster than before to changing business conditions.

The term business intelligence appeared again in 1958 in an IBM System Journal article written by Hans Peter Luhn entitled A Business Intelligence System. In this article, Luhn described the concept as follows: "Business Intelligence is the ability to apprehend the interrelationships of presented facts in such a way as to guide action towards a desired goal." In the 1980s, the term was popularized by Howard Dresner, now CTO at Hyperion Solutions. In 1989, Gartner Group introduced their report Business Intelligence: Competitors in the Warehouse Market, describing the various processes and structures involved in helping companies use information to better manage operations and make decisions.

2.1. Definition and Importance

In 1958, IBM defined business intelligence (BI) as “the ability to apprehend the interrelationships of presented facts in such a way as to guide action towards a desired goal.” Over the years, intelligence has been all-encompassing, and intelligence has been developed for distinction in various areas such as military, government, meteorology, agriculture, transport, weather forecasting, and crime prevention. However, this chapter focuses on business intelligence for different businesses. Business intelligence is considered as a firm asset using data to understand the market and customer needs and providing the data and information to the correct person in the organization at the right time and place.

Furthermore, BI is the ability to perform the analysis of information that has been collected for decision making, thereby managing the business effectively. The application of the correct BI tools and techniques to various sectors provides knowledge that aids the development of the economy. Business intelligence is disclosed as good quality information management, which is accurate, simple, rapidly accessible, and pertinent [2]. The demand for BI is constantly growing throughout the world to support business development and expansion. Therefore, the actual applications of BI tools and techniques in retail, healthcare, financial services, manufacturing, and telecommunication are crucial to understanding the efficiency of BI in practical existence as implemented in various other real commercial sectors.

2.2. History and Evolution

Business intelligence (BI) deals with connecting the right data with the right people at the right time to support better decision making and improve business performance. The term also refers to a specific set of business analysis related technologies and practices. As businesses have become increasingly competitive and challenges have grown in all areas, the need to provide decision makers with the information they need to steer the business becomes even clearer [2,4,5]. Business Intelligence can provide business critical information and enables organisations to take informed business decisions and compete successfully.

Decision Support is an area within Management and Information Sciences, which is dedicated to supporting business decision making, often using modelling technology. Decision Support Systems focus on providing support for more complex decision making and business modelling. The concept of Decision Support, involved in providing support and intelligent analysis for more complex processes and modelling lies at the heart of Business Intelligence [6-8]. As the terminology has evolved and the number of tools increased, therefore, the term Decision Support changes to Business Intelligence. Business Intelligence is the art of managing, manipulating and displaying data and information associated with the data in ways that provides useful business information. Business Intelligence is not a new concept. Indeed Business Intelligence has been discussed in academic literature since the 1950s. Howard Dresner of Gartner popularised the term."

3. Business Intelligence Tools and Technologies

Business intelligence (BI) combines data warehousing, analytical processing, data mining, reporting, and monitoring technologies that help users possess an intimate knowledge of the customer's experience on one product or service and gain insights into the particular business process. Modern BI tools provide historical, current, and predictive views of operations. Common functions of BI technologies are reporting, online analytical processing, analytics, data mining, process mining, complex event processing, business performance management, benchmarking, text mining, predictive analytics, and prescriptive analytics. These functions can be used in various sectors, including retail, healthcare, financial services, telecommunications, and manufacturing.

The transformation of data to information always requires both the tools as well as the appropriate technology. There are three main forms of business intelligence systems: tools, applications, and practices [9,10]. Systems represent the various levels of development of all the above, which can be divided into the results of support, the form of data needed for BI, the technological background at the data warehouse level, the methods of data collection, and the users necessary for BI programs (Dawson, 2016). Business Intelligence in practice is realized through digital universe growth, the use of operational information to support user services, increased flexibility in using information, the growing importance of Business Intelligence Solutions, new features of applications supporting decision-making (Intelisale.com, 2017). Basic Business Intelligence tools include data warehouses, operational data stores, data marts, information brokers, and metadata.

3.1. Data Warehousing

Data warehousing comprises the first step of a business intelligence solution, helping consolidate data from various sources and transform it into convenient formats for analysis. The subsequent stages involve analysing the consolidated data and visualizing the results. Several techniques, such as data cleaning, data consolidation, data integration, data aggregation, and data cataloguing, are employed during the data warehousing process.

In the retail sector, for example, companies maintain huge customer bases and frequently require information about customers' purchase behaviours and patterns. Stores that issue credit cards often provide cash discounts to loyal customers and generate reports based on the number of visits. The warehousing system can provide reports about different sections of customers, allowing discount offers to be made accordingly. Besides helping with customer data, business intelligence in retail store chains can be utilized for inventory management, sales forecasting, and merchandise scheduling.

3.2. Data Mining Techniques

Data mining, an important component of business intelligence, is the process of analysing data from different perspectives and summarising it into useful information. Pattern discovery in data mining provides users with useful information in an undirected manner. It allows users to discover information that is not readily evident in the database neither through direct query nor using OLAP tools. Pattern discovery is also called knowledge discovery in database, exploratory data mining and data dredging[11-13]. It is often used to discern patterns in business such as what customers buy, why customers leave the banking service etc. Classification assigns items in a collection to target categories or classes. The goal of classification is to accurately predict the target class for each case in the data. Prediction strives to construct models for the future. Clustering is a technique which divides data into meaningful or useful groups or clusters. Outlier analysis is the mining for data records that do not comply with the general behaviour or model.

Applications of data mining can be found in almost every aspect of our lives such as marketing, banking, manufacturing, telecommunications and so on. The businesses are always seeking opportunities to extract useful knowledge from the databases for the purpose of decision making, market analysis, predicting trends and behaviour and cutting costs. Data mining can also be used for fraud detection, customer buying behaviour analysis, employee performance analysis, customer churn analysis.

3.3. Visualization Tools

Visualization Tools business intelligence application is used to present data to support decision-making. Data visualization tools are not new but the rapid progress in areas like client-server technology, Object-Oriented development, OLAP, Mobile & Wireless computing, and the Internet has increased Visualization Tool capabilities. As a result, there is a renewed interest in these tools [2,14-17]. The main goal of these tools remains unchanged — facilitate user understanding and interpretation of information by presenting it in the most appropriate form—in short, the visualization of information.

Visualization Tools are used to present data to support decision-making. These tools, although longstanding, have evolved alongside technological advances such as client-server computing, object-oriented development, online analytical processing (OLAP), mobile and wireless computing, and the Internet. These developments have expanded the capabilities of visualization tools, renewing interest in their use. Despite these changes, the fundamental objective of visualization tools remains constant: to enhance comprehension and interpretation by presenting information in its most effective visual form. Visualization is particularly valuable in representing complex data relationships and structure, providing intuitive overviews of large-scale data, and supporting strategic decision-making through charitable representations of growth and trend analysis.

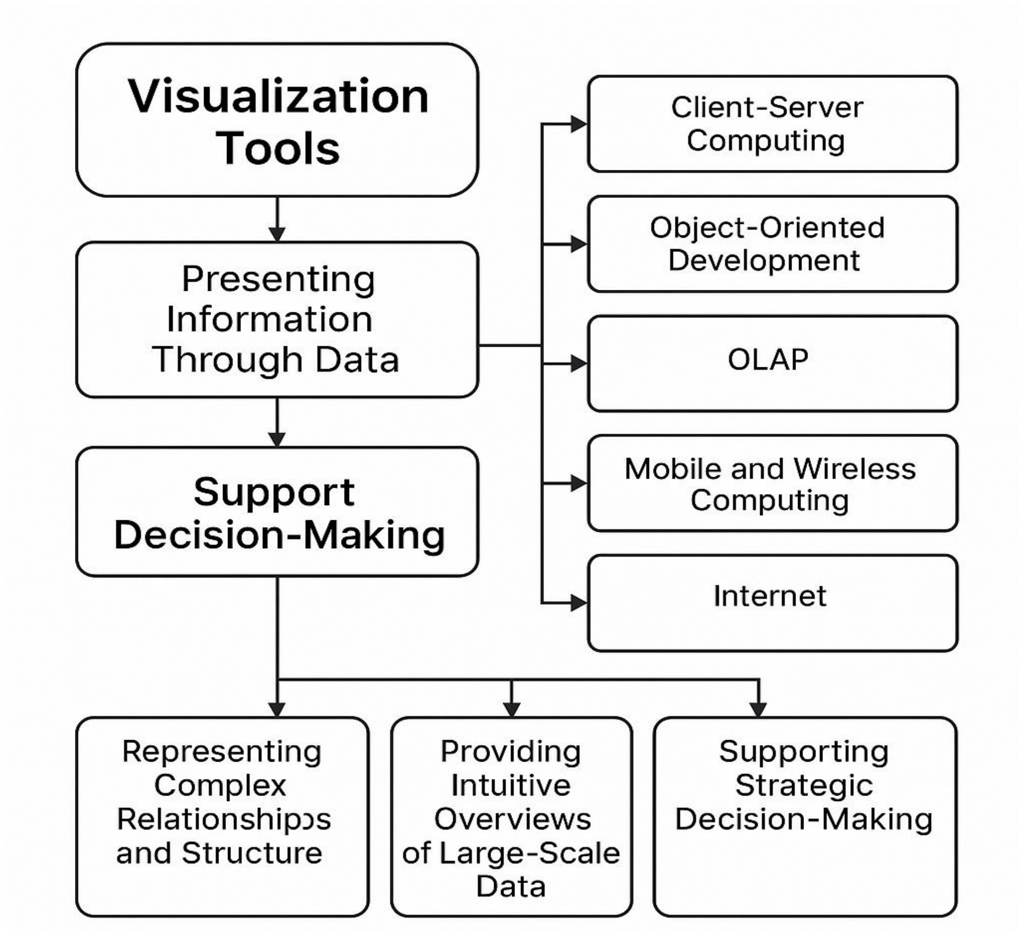

Fig 1. Visualization Tools

4. Applications in Retail Sector

When utilizing business intelligence within retail operations, data mining techniques can effectively support decision-making processes. Dynamic reports can assist in areas such as customer behaviour analyses, product and service response evaluations, benchmarking between sales periods, and sales forecast estimations [9,18-21]. Additional factors influencing a retailer's success—like efficient inventory control and management—can also be addressed with the help of business intelligence data mining tools.

The healthcare industry can benefit from business intelligence tools by analysing vast quantities of patients' data, enabling cost reductions, improved service quality, and the management of disease outbreaks. Complex reports are crucial for hospitals and other healthcare institutions as they drill down through clinical data to discover the root causes of events. Business intelligence focuses on providing a 360-degree view of patient journey activities in near-real time. Advanced capabilities might include logistics support and resource allocation management, as well as additional facets that enable healthcare organizations to easily analyse historical data and predictive models to discover insights about patients and diseases.

4.1. Customer Behaviour Analysis

The analysis of the behaviour, desires, and needs of customers, as part of marketing management, poses a considerable challenge for marketing specialists. Detailed knowledge of consumer needs facilitates the promotion of specific product categories [22,23]. Market basket analysis support programs answer ancillary questions, such as: Which products are most often purchased together? Which customers generally buy specific products? Which products guarantee high revenue? Which customers purchase products prone to overstocking? This relates to, for example, related products (bread and butter), products with increased risk of overstocking (milk), or the association of overstocking with other products.

In the context of the retail sector, the analysis of customer behavior is crucial. Numerous products are mediocre, regardless of their contents for the customer; if the price is too high, customers evade, and competitors obtain their money. Consequently, the customer will not demand an excellent product to satisfy their needs better. The marketing-and business-intelligence departments of retail organizations support proper relationships with customers by analyzing customer shopping habits. This information guides employees in designing and investing in effective sales.

4.2. Inventory Management

Inventory management is a business function for maintaining a specified level of stocks on hand to meet demand of the customers. Managing inventory is a very critical aspect for companies as the ordered inventory and applied stocks should be perfect [24-26]. Both over population and under population invasive inventory mistakes which a company need to be alert. Over population of inventory can result in large inventory carrying cost which includes maintenance, taxation, insurance, handling, fear of damage, expiration etc. Stock-out condition leads to scarcity of materials which directly affects the customer response time for delivery of product.

Inventory is an asset and the flow of inventory affects the representation of financial status of the company. Inventory turnover is generally calculated to estimate the number of times the inventory was converted into sales revenue in a period. For better analysis of inventory turnover, the estimation should be in monthly basis rather than yearly basis.

4.3. Sales Forecasting

Sales forecasting enables organizations to predict future demand for their products and services. This process heavily relies on historical data related to sales, stock levels, and the outcomes of various promotions and campaigns [27,28]. Accurate sales predictions are fundamental in formulating business plans that supply the necessary products and services in expected quantities. Moreover, organizations can precisely estimate product prices to secure higher profits. Business Intelligence tools employ Data Mining techniques to extract meaningful information that aids in analyzing historical data and, consequently, making accurate sales forecasts.

Forecasts generated through such methods inform decisions regarding product pricing, campaign execution, promotion strategies, discount offerings, and budget planning, all aimed at optimizing sales volumes. Nearly every governance and decision-making unit within an organization depends on a dependable sales forecast to manage financial planning and inventory distribution in an efficient and profitable manner.

5. Applications in Healthcare Sector

In the healthcare sector, where business intelligence services are consistently on demand, the primary focus is on analyzing patient-related data. Such analysis not only enhances patient care but also provides invaluable insights to suppliers and hospital superintendents. Particularly compelling are BI tools that can predict medical conditions and recommend personalized treatments [19,29-31]. Western hospitals, in the quest for improved patient experiences and effective marketing research, have increasingly turned to the continent-oriented healthcare system. Various BI tools are currently deployed in this arena, including data warehouse models that feature complementary OLAP components.

The application of data mining techniques in healthcare service analysis is gaining momentum. For example, clinical data mining enables researchers to formulate hypotheses regarding the causes of specific disease occurrences. Additionally, data mining methods are valuable for optimizing health services within hospitals.

5.1. Patient Data Analysis

In a hospital, the patient's data is analyzed using pattern-extraction techniques. This analysis takes into account the gender, ethnic origin, and age group of the patient to predict the regions that have a high number of patients with a particular kind of illness. This information becomes indispensable in making the hospital's required arrangements for equipment, beds, staff, and training within that region [32,33]. Healthcare can be greatly improved through better understanding of patient requirements. With patient behavioral data, a pharmacy can engage in effective marketing strategies, while hospitals can tailor their services intelligently for patients, and insurance companies can provide informed plans to patients.

When analyzing patient data, recommendations can be made in several key areas, including (i) Medical—predicting the future age group of a patient, suggesting a healthy diet, personal health analysis, and better treatment; (ii) Organizational—detecting diseases affecting large numbers of people in a particular area, suggesting the planning of training programs or awareness camps to avoid the spread of the disease, and managing inventories of medicines, bed strength, and other related activities; and (iii) Financial—predictions related to insurance purchases, offering effective insurance packages, and insurance risk evaluation. Additionally, these predictions can be employed in the development of new medicines by the pharmaceutical industry.

5.2. Operational Efficiency

The operational efficiency of an organization can be significantly improved through Business Intelligence techniques. In current competitive scenarios, organizations are striving hard to curtail wastage, reduce cost, and enhance productivity [34-36]. The present environment demands that the organizations react faster in order processing and delivery to reduce the lead time. The decisions necessary to manage the short cycle time depend a lot on the dynamism in operational functions and also on the accuracy in demand forecasting. Business Intelligence tools help the organization in adequately addressing the dynamics of operational functions by extremely analyzing the operational activities and the relationships with the other functions. The demand forecasting process also becomes precise and helps the organizations to be ready always in the supply chain to avoid wastage of perishable goods and avoid the inventory pile-up in the case of durable goods.

5.3. Predictive Analytics in Treatment

The rapid increase in the volume of medical data generated in hospitals—including computerized case notes, online appointment records, and transactional and billing data—makes it difficult to provide more effective treatments without the application of advanced Business Intelligence (BI) techniques [37-40]. By applying BI methods to these complex sources, patients may receive medical care more quickly and with higher quality.

Predictive analytics uses BI technologies to detect the movement of people, whether patients or staff. Associative data mining techniques applied to ad hoc medical data brochures can reveal significant relationships. Feature detection and tumor analysis are classical BI techniques applicable to medical imagery. Disease prediction can be achieved by detecting relevant symptoms quickly. Process mining applied to hospital resource management is used for bed planning, emergency assessment, and resource KPIs. Predictive analysis techniques can also be employed to foresee future disease patterns. This enables timely preparation for new disease outbreaks and facilitates early preventive measures, thereby reducing the occurrence.

6. Applications in Financial Services

Financial services have been garnering considerable attention because of the risks on both sides of the financial spectrum. Business intelligence drives risk management functions in banks and financial institutions. An integrated data warehouse provides a repository for all data relating to customer transactions and business performance. This uses a wide range of data mining techniques to generate information for all decision-makers in distributing capital to the appropriate areas of business and controls the process by containing and identifying all types of risks that a financial institution faces, including credit risk and market risk [41-43].

Not all risks are associated with adversity; the bank manager also wants to understand the current position of the bank in terms of market growth and customer acquisition in different areas. In the current account opening area, the bank manager can obtain information from the business intelligence system about the market in terms of customer acquisition and distribution geography. Another area affected by risks entering the market is the branch of a bank itself, where BI provides a measure of risk associated with the opening of new branch offices. The financial institution is also interested in predicting the effect of investments undertaken. Another area where business intelligence is used frequently is in operational risk. Business intelligence helps the bank manager in throughput prediction, address verification, alteration verification, and so on.

6.1. Risk Management

The financial services sector greatly benefits from business intelligence (BI) as it serves companies that provide insurance or actively manage money held in investments such as mutual funds, pensions, and hedge funds. A company that offers business intelligence consulting services can help achieve operational efficiencies and facilitate the use of valuable customer information.

The principal objective of BI is to provide consistent information that supports risk management in the financial sector and in any business environment. Many companies still use legacy systems for their business intelligence processes, which restricts the type of information that can be extracted. These systems gather information from various lines of business and combine it into a unified view of the company [28,44-47]. Data for this process is drawn from multiple sources such as manufacturing, distribution, retail, marketing, and finance. Each source may reside in a different type of system—for instance, data might originate from an enterprise resource planning system, enterprise data sources, or customer information databases. Different systems and user types require information designed specifically for their needs.

6.2. Fraud Detection

Fraudulent activities in various domains such as banking, credit card services, health insurance, telecommunication, and the internet make the area of fraud detection and fraud prevention one of the most crucial requirements. Fraud detection is the process of identifying whether customers have committed fraud [48,49]. Fraud detection is a very difficult task due to the multifaceted and hidden nature of customer behavior, making explicit assessment challenging with the help of business knowledge and simple models.

Therefore, data mining methods are employed to detect fraud instead of a traditional approach that relies upon human expertise. Common fraud detection techniques are Artificial Neural Network, Support Vector Machine, Genetic Algorithm, Decision Tree Analysis, Clustering, and Hybrid techniques [3,50-52]. Banking is one of the fastest-growing services worldwide, with every bank trying to maintain its business information to provide accurate service. However, malicious attacks on data are seen very frequently. Fraudulent transactions may occur due to these malicious attacks. Data mining techniques are used to analyze the data stored by the banking services to detect fraudulent transactions. Credit card fraud is an unruly transaction made by any unknown user using a credit card of the bank. Data like Customer Name, Transaction, and Visa Type are examined. Data mining techniques are used to detect fraudulent transactions and help in analyzing the behaviour of the clients of a bank.

6.3. Customer Segmentation

The financial services sectors use business intelligence (BI) to analyze their customers' needs and to develop customer value management (CVM) programs. Customer Segmentation is a type of CVM program, which is essential to any business [53-57]. Businesses can use BI on customer segmentation to develop specific strategies for their key customers, a strategy for developing customer loyalty and for acquisition of more customers.

Business Intelligence can be applied to an individual customer, either existing customers or a potential customer. Customer profiling enables financial service companies to know the characteristics of their product-holders and non-product holders. This information can be used for the retention of product-holders and the acquisition of non-product holders. Customer behavior analytical shareholders enables the financial services companies to know customers' transaction behavior for a specific product. This information can be used to control the fraud and the unauthorized transactions.

7. Applications in Manufacturing

The application of business intelligence (BI) in manufacturing sectors can bring sensitivity to all levels of decision making in the organizations. Based on the analysis of manufacturing aspects that need BI support through the value chain, the support can be mainly towards supply chain, quality control and production [58,59]. The application of BI within the manufacturing industry is also supported by many e-BI vendors such as SAP, Oracle, IBM, MicroStrategy and Cognos. One example of business intelligence support and operational monitoring within the manufacturing industry is at Southern Morning Herald Ltd (SMHL), a company in the print and publishing propaganda industry. SMHL uses Business intelligence for analyzing operational performance by monitoring, reacting and exploring daily performance within the factory. The users within the production environment can, through the supply chain domain, perform operational monitoring to ensure that production runs smoothly at all times.

Production control domain supports the production regarding production statistics while the quality control domain facilitates the checking of the production quality of the operation on a daily basis [60,61].

In addition to the support in the supply chain, quality control and production aspects, business intelligence can also provide some level of predictive analysis.” Prediction of the possible maintenance failures can reduce cost in operation as the unscheduled maintenance will not disturb the production schedule. The call for tenders for preventive, repair and overhaul contracts can be proposed by taking contents of the possible maintenance prediction. Prediction of product failure can reduce service volume and reduce maintenance cost through reengineering the product configuration. Finally, analytical prediction model can deeply support service center such as management of spare request given the provided tenders for spare parts. The application of the other business intelligence aspects in manufacturing is the support through the production control. Monitoring the production control aspect can lead to reduce delays in deliveries because it allows better process control and faster response.

7.1. Supply Chain Optimization

The modern business environment is dynamic and challenging, with organizations confronted by escalating costs, leaner margins and resources, and growing customer demands for high-quality products and services at competitive prices. Supply chain management (SCM) aims to respond effectively to these pressures by optimizing the sourcing of materials, warehousing, distribution, and delivery to end customers. This optimization relies heavily on efficient management of information flows and communication among the major players in the value chain. The need for systems and technology capable of predicting potential disruptions and mitigating risks is therefore paramount.

Business intelligence (BI) is particularly suitable in this context due to its data-driven methodology for improving decision-making and capitalizing on business opportunities. The entire business process benefits from insights uncovered through BI [62-64]. These insights facilitate the establishment of reasonable arrangements between buyers and suppliers, enable the detection of potential disruptions in the supply chain, and help identify competitive brands that might influence market dynamics. Additionally, they provide advanced alerts about likely future scenarios within the supply chain. "Sleepy stores," which can have an adverse impact on the retailer–supplier relationship and affect other business functions, are a concern, as are fast-selling stores that could lead to stockouts and unsatisfied customers. The supply chain process encompasses all related steps from supplier selection to end-customer delivery. During the sourcing of raw materials, the aim is to negotiate prices and delivery times in a way that ensures material availability at the right time and place, while optimizing costs.

7.2. Quality Control

The first step in analysis is the identification of the key problem: Which laymen are in the right place but who to the wrong, so also the correct location of materials in the wrong place it is necessary to discover. Due to the deeps of management, it is difficult to keep the system correct and more systematically. The manufacturing sector requires a great volume of resources. If the management of resources is not accurate, then it may lead to depression of the industry indeed. The application of BI tools effectively resolves the problem mentioned earlier.

Because every industry is supplied with a large number of raw resources, which are responsible for the production of the finished product. Resources are appropriately managed with the help of the business intelligence tools. The transformation of business intelligence and advanced information technology can assure that every customer inquiry turns in more wealth, business, and loyal relationship with customer [65-67]. BI has shown intraclass correlation and average scoring, which leads to the better customer loyalty. Customer loyalty is achieved by companies through long-term business relations, which are interoperable and reliable. With the help of BSI, regardless of how the conditions change overtime, it has been hypothesized that for better resource utilization, an organization should have enough market orientation.

7.3. Production Efficiency

The quality of business intelligence is an essential point for production efficiency in some cases, since business intelligence can predict major disasters in production such as quality of the product or defect rate of the product goes outside of acceptable yield. Business intelligence also can recognize the causes of problems. Armstrong World Industries is an example of such applications [68-70]. Utilizing TIBCO Spotfire, Armstrong creates a knock-out visualization tool to monitor industrial data and clarify production gaps before beginning new production, which decreases unexpected factors and defects of products. They claim that by using this tool, they achieve increase productivity, yield and quality with real-time insights.

In case of supply chain management area, business intelligence has been improving supply chain in terms of cost, delivery, quality and productivity. DHL Supply Chain and GT Nexus benefits from Spotfire Visual Analytics. These companies applied TIBCO Spotfire to their portfolio of services and products in order to provide shipment intelligence. It is possible to find production efficiency thereafter. For example, DHL Supply Chain provides an alert for the unexpected event, so the whole company can take action at the right moment.

8. Applications in Telecommunications

Information technology has led to the convergence of data, voice, and video services for the telecommunication industry. Modern telecommunication companies operate in a highly dynamic environment due to changing customer needs, increasing competition, and rapid technological changes. This dynamism necessitates adequate information for decision-making and responsive management. Business Intelligence (BI) methods are being widely adopted with the aim of acquiring a competitive advantage or improving the company's competitive position.

Customer and revenue growth have been the main areas of focus for many telecom companies during the past decade. Nevertheless, organizations have faced many difficulties in growing revenues through new customers. Companies fail to strategically analyze customers' characteristics and needs, and pinpoint which customers are more valuable or at risk [55,71-73]. The telecommunication marketing managers lack a grounded appreciation of customers' tastes and preferences. The development of a customer attrition model, based on company and market information, is necessary to understand customer preferences and structure successful retention campaigns. Churn rate analysis in the telecom sector is vital for identifying customer segments and addressing turnover causes. Turnover prediction is a key factor in managing customer attrition.

8.1. Churn Prediction

Telecommunications is one of the largest and most competitive industries, generating and storing a huge amount of data about customers, sales, network traffic, cost, and maintenance. Analyzing these data to identify hidden meaningful information can provide a great advantage to any company, enabling implementation of efficient marketing plans, well-focused service, and better customer relationships. Despite this high cost, many customers discontinue the relationship with the firm once the sales are very low or the service is not satisfactory. For relatively high profit customers, the firm should especially act to retain them, as the cost of creating a new customer relationship is 6–7 times more than the retention cost.

Customer attrition or churn prediction is one of the most important and challenging problems, as the company has all the data required for the churn customer identification, but often fails to predict in time. Many churn prediction models have been proposed and used. However, the main problem in churn prediction is the imbalance in the dataset, where survival customers are very high and churn customers very low. Most techniques, when applied to the whole dataset, classify all customers as survival, causing misclassification of churn customers. Therefore, the class imbalance problem becomes an important issue in churn prediction. Various stages of a churn prediction system—from raw data to deployment—and the techniques used from data cleaning to model building are presented in Figure 8.1.

8.2. Network Optimization

Telecommunication companies often find supporting an ever-growing subscriber base to be a difficult task. Due to the introduction of MVNE (Mobile Virtual Network Operator) model/the increasing rate of MVNOs, the number of subscribers increases at an even faster rate than predicted. With a large database of subscribers and numerous competitors, it is imperative for companies to ensure good customer relations and offer the best services, since in the highly competitive scenario, the loss of a single customer can have serious repercussions on the business [26,74-76]. Business Intelligence (BI) tools offer companies an insight into operations ranging from network optimization to customer shut switch prediction and support effective long-term planning.

The advice given by Business Intelligence tools helps the management to take the necessary action. Take for instance, a report that breaks down support tickets by package, showing a high number of faults for a particular package. When business managers see this, they will check the root cause of the problem and decide if it is worthwhile to continue to offer this package. If many customers cause a high number of faults and require ongoing support, it neither benefits the company nor the customer to keep offering the package.

8.3. Customer Service Improvement

Business intelligence supports customer service activities in the telecom sector. The following are examples of customer care and help desk applications:

An Ad Hoc Query tool enables non-technical users to create ad hoc reports to answer simple binning or segmentation requests without requiring spreadsheets and macros, which take time to create and are prone to error. Customer-service representatives can get a 360-degree view of the customer through a consolidated view of usage, billing, and call center information. Knowledge-management applications facilitate the easier location of call-resolution documents for use during customer interactions. Additionally, call-dispensation techniques automate individualized responses to customers who call; are based on computed propensity-to-churn scores; and help build call scripts on the portal for customer-service representatives.

9. Challenges in Implementing Business Intelligence

Business intelligence (BI) aims to support better business decisions, helping organizations to gather, store, access, and analyse data to make more informed choices. Nevertheless, in practice many countries have been able to use BI approaches only for a few selected segments, lacking an integrated data-capturing and/or information-flow mechanism [77-79]. Many organizations thus face challenges in operationalizing the BI capability. Typically, designing BI within a firm involves the following steps: developing an enterprise data warehouse; developing the sales report at the department level; developing the sales forecast and the market analysis report for the sales and marketing function; developing the customer analytics report for the marketing function; developing the supplier analytics report for the purchasing function; and developing a product- wise sales analysis report for the product development function. These challenges typically fall into the following broad categories.

Moving to BI without cleaning the legacy business environment leads to poor-quality data. The focus must be on the core business need and not on the flashy presentation of BI. One main feature of a BI system is to correlate information from various functions within a business organization, but sometimes the floating information of each single department is conflicting because of isolated management in each area. Another constraint is the availability of hardware and software suitable for BI. Also, there is a lack of business-operations knowledge in every aspect of the business and the BI area, which creates a gap between the business-operations team and the BI team (business or technical). This makes it difficult to implement BI in the business process. Another important factor is the expectation mismatch; management has a lack of understanding and clear focus about BI's scope and capabilities and considers it to be a mere decorative information-extraction and information-representation tool.

9.1. Data Quality Issues

Data quality is a key determinant of the usefulness of a data warehousing project. Since data warehouse is data originating from many heterogeneous sources; inconsistencies and redundancies are removed before data is stored in the warehouse. Data cleansing programs are used for warehousing to ensure the quality of data. One main problem is that most of the data cleansing processes are manual, time consuming, and error prone.

Data quality is usually improved by applying standardization techniques such as extracting city names from a full address for further grouping. The criteria for measuring data quality include accuracy, completeness, consistency, timeliness, and conformity [80-83]. Other characteristics of data quality are relevancy, usability, accessibility, value to cost ratio, and reputation. Inaccurate, inconsistent, and obsolete data adversely affects business. Ensuring high levels of data quality will resolve many problems. These problems can be resolved through improved training methods, data auditing, effective use of data entry front-end tools, framing effective data quality rules and management, and improved procedures at data entry points.

9.2. Integration with Legacy Systems

Business Intelligence (BI) systems are required to integrate with other on-line enterprise software systems such as customer relationship management (CRM), enterprise resource planning (ERP), and supply chain management (SCM). Moreover, since many organizations have legacy systems, a critical consideration with respect to the BI system is the system must be able to extract, clean, and transform the operational data housed in legacy databases into a format suitable for the data warehouse.

The rapid growth of transaction-processing systems over the past 30 years has resulted in a disconnect in many organizations between the operational data stores and the decision-support systems. Currently, operational data is often stored in legacy transaction-processing systems [84-86]. The overhead required to support the decision-making process of these systems is so great that they cannot be accessed to support analysis. The result is an expensive paper-based, turn-around analytical process that provides management with information that is often too late and outdated. To address this problem, many organizations have implemented data warehouses. Data warehouses are used to store historical data used by decision-support systems.

9.3. User Adoption and Training

Investing significantly in business intelligence to provide robust capabilities does not guarantee the anticipated returns. The final success of a business intelligence system is determined by its ability to engage the targeted business users actively in exploring and querying the organization's data for a wide variety of use cases and scenarios. Although business intelligence vendors frequently present their products as "easy to use"—eliminating the need for training—this assertion is valid only for extremely simplistic environments. Users typically require training to familiarize themselves with the environment and solve common business problems or to replicate information products relevant to their day-to-day work.

Understanding the composition of the end-user population is a main focus when planning a business intelligence implementation. The population is usually segmented into technology-illiterate users, casual Microsoft® Excel® users, and curious business analysts capable of generating their own complex reports. The needs of these groups vary: the business analyst uses analysis tools, the casual user resorts to dashboards, and the technology-illiterate user depends heavily on predefined canned reports. Depending on their usage levels, selected users may be required to assist in the training of other new users. Implementation success depends heavily on establishing a comprehensive training and user certification program with run-the-business support available through the help desk and a dedicated website.

10. Future Trends in Business Intelligence

Business intelligence (BI) is continuously evolving, driven by breakthroughs in computer technologies and the rapid growth of information and communication technologies, all aimed at enhancing the decision-making processes in organizations. Traditional BI technologies depend heavily on the availability of quality, large-volume data collected from different internal information systems. Many organizations in different sectors have sizable amounts of historical data that can be used in a BI process, regardless of their nature. However, the value of such data remains unexploited if a BI process is not implemented. The area of BI systems has experienced significant growth in recent years, a trend expected to continue. Organizations expect to gather data from many sources, contained within multiple legacy systems or third-party sources, and still be capable of making analyses including information from all potential sources in a centralized environment. This rapid development of BI applications enables organizations to make informed decisions, resulting in potential cost savings, waste reduction, and business growth.

The dependency on readily available clean data for BI has been challenged in recent years with the emergence of artificial intelligence (AI) techniques in analytics. AI enables the analysis of new data types such as blogs, images, and MD (biology) data, which may be sourced from internal or external business environments [18,87-89]. Additional developments in BI are moving towards the implementation of advanced analytics for analytical prediction and business behavior prediction. In due course, BI analytics will support real-time decision-making by integrating BI systems with operational systems. Artificial intelligence is expected to play a vital role in the future development of business intelligence systems, ensuring that BI applications are capable of timely and accurate market predictions.

10.1. Artificial Intelligence Integration

Artificial Intelligence (AI), which describes machines, intelligent agents, or intelligence demonstrated by computers, necessitates Business Intelligence (BI) to interpret, categorize, and act on the information garnered. There are three primary avenues through which BI will utilize AI: AI-powered Augmented Analytics (AA), AI operationalizing into BI, and the embedding of AI functionalities within BI mechanisms.

Augmented Analytics represents the installation of a layer of AI onto data analytics systems. Analytics refers to the inference of hidden or important knowledge from data, and when AI is incorporated into Enterprise Knowledge Investigation systems, Augmented analytics is produced. AI operationalizing constitutes the deployment of AI into the business process through BI implementations [31,33-35]. As described in UIPath's enterprise automation blog, AI operationalizing entails starting with a business inquiry, discerning the decision points in the business operation that impact the business question, leveraging AI to arrive at informed decisions, and incorporating those decisions into the business process for real-time implementation. AI embedding involves the integration of AI functionality within BI apps, plugins, and BI-system components to enhance and refine those processes.

10.2. Real-Time Data Processing

Real-time data processing is a broad area encompassing data stream processing, complex event processing, and event stream processing. When applications or use cases demand the need for real-time analytics, historical data analysis by business intelligence tools is helpful to the extent that contemplating the possible past of the system at any moment of time can provide an indication to the future of the system.

For instance, credit card fraud detection is one such critical fraud detection process where real-time analytics tools take precedence. Applications detecting such unusual behavior in real time can be used to identify specific frauds and immediately stop the transaction from proceeding. On the contrary, big-data business intelligence applications are much more suited for analyzing traffic jam predictions on any area of concern over a broad period of time. Though such analysis is time sensitive, it is still part of a much larger analysis.

10.3. Increased Focus on Data Privacy

Just like in many other industries, there are many logged events, browsing and buying behaviours so increased focus on data privacy is being experienced in the retail sector as well [38,62-63]. Business Intelligence technologies can accelerate harmful exposure if deployed without controls and canplay a major role in harmonising the collection of data andproviding protections to customers. Consultancy firm Gartner has published a report covering business intelligence and analytics as the key trend of the shift to an "Immersive Experience". Gartner has forecast that by 2018 smart machines will practically govern their own existence.

11. Case Studies

Business Intelligence (BI) applications have proliferated across various sectors, encompassing many different tasks. The main sectors that have been influenced by the widespread use of BI include retail, healthcare, financial services, telecommunications, manufacturing, and other businesses. Increasingly companies are making use of BI systems and processes to analyze their data and gain insights into their business. Accordingly, a wide range of applications, practical experiences, and case studies have appeared in the BI literature.

Retail organizations have exploited BI to analyze customer buying habits and to improve their ability to manage stocks and sales, while BI has also been used in the healthcare sector. The healthcare decision makers have used BI tools to analyze patient data and improve the operating dimension within hospitals [3,45-48]. The Financial Times users have also reported similar problems related to the use of BI systems in the financial services industry, while manufacturing is suggested to be one of the sectors that can benefit most from the use of BI applications.

11.1. Retail Success Stories

Business intelligence (BI) is the process of collecting data and extracting useful information from it. Several tools for managing information are being developed to fulfill all the requirements of businesses. These tools include data warehousing, data mining, OLAP, cluster analysis, and visualization tools. BI has a wide array of applications in all sectors, owing to different organizations' vast stores of information. BI tools are essential in every sector, with some being especially strengthened by business intelligence, such as retail, telecommunications, banking, manufacturing, and healthcare. Successful implementation of BI techniques in one sector should encourage replication of these techniques in other sectors.

In the retail sector, BI is used to support various functions, including analysis of customer behavior and satisfaction, inventory analysis, and store performance. For example, RetailPro is a POS and retail management software that offers sales reporting and customer profile analysis. Business intelligence solutions help harness data to develop a clear picture of customer needs and shopping patterns, enabling retailers to promote products and services strategically to their target market segments. BI tools are also crucial for marketing strategy planning and forecasting sales and profits.

11.2. Healthcare Innovations

Business intelligence (BI) refers to the processes, technologies, and tools that transform unprocessed data into meaningful business information for analysis and application in decision making [9,46-48]. Technological advances in information systems coupled with the rapid expansion in source data have enabled and required the use of BI in everyday decision-making processes. BI plays an essential part in virtually every commercial enterprise, helping managers direct human and capital resources.

Novel BI applications in healthcare can save lives, improve patient outcomes, increase the quality of care, boost operational efficiency, and forecast health-related trends, treatments, and symptoms. The sector poses a particular challenge for BI because users typically lag other organizations in terms of IT adoption [6,60-62]. The example of a hospital providing clinical services, ambulatory care, diagnostics, and treatment to serve its patients helps illustrate the potential of BI. Quality services at a reasonable cost and improved patient convenience and satisfaction are some of the key goals of the hospital. Dedicated resources, such as the management team, must be committed to the BI initiative to monitor key performance indicators, including patient wait times, readmission ratios, patients seen per day, and cost per patient treatment.

12. Conclusion

Business intelligence (BI) applications in different sectors clearly indicate that the data warehouse concept is not future-oriented but comes from the business world. Moreover, the sector-specific operating environment and needs are spurring new developments in the nature and structure of the data warehouse. Indeed, the data warehouse concept has endured both the business world's concept shifts and young field syndromes, so that new phases of BI and data warehouse are being applied. In many countries and sectors, BI and related data analysers are used not only for-profit maximization, but also to serve the community by improving living standards, protecting the environment, and similar objectives.

Understanding the concept of BI still involves examining the warehouses in which we store our information. In this context, making the right investments to obtain meaningful, fast, and reliable reports that support management decisions in an environment of global business competition constitutes a strategic decision for organizations. Additionally, the ability of organizations to consider developments in information technology domains such as data warehousing, data mining, and knowledge discovery is vital for surviving and expanding business operations in rapidly changing operating environments.

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