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The Transformational Impact of Modern Data Warehousing on the Banking System

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Abstract: The banking industry is undergoing a significant transformation driven by technological advancements, and modern data warehousing has emerged as a critical component in this evolution. This review paper examines how modern data warehousing is transforming the banking system, highlighting its impact on data management, analytics, real-time processing, regulatory compliance, customer insights, personalization, scalability, and cost efficiency. By synthesizing the existing literature and industry practices, this review aims to provide a comprehensive understanding of the role of modern data warehousing in reshaping the banking landscape.
Keywords: Data Warehousing, Modern Data Warehousing, Modern Data Warehousing in Banking

I. INTRODUCTION

When compared to other sectors of the economy, the banking sector has one of the greatest information demands. Business intelligence (BI) has been more important in the banking industry as technology has advanced. The necessity for financial intelligence has become more apparent in the face of accelerating economic cycles and intensifying competition. [10] The capacity to collect, handle, and analyze massive amounts of information on bank clients, services, operations, suppliers, partners, and transactions is what we call "bank intelligence."

DW is a solution to the growing dilemma of how to gather, manage, and convert massive amounts of data into actionable insights. There are a wide variety of data warehouse types made to help the banking sector.

In this paper, we provide you a snapshot of the banking sector as it is right now, with an emphasis on the increasing relevance of data-driven decision-making and the difficulties inherent in using conventional methods of data management. It explains why we're doing this evaluation and how contemporary data warehousing can be a game-changer.

1) *Data Management Transformation:* The effects of contemporary data warehousing on banking data management are explored here. Data quality is addressed, and better data accessibility and data consolidation are also covered. This section also delves into the capabilities of contemporary data warehousing with regards to data governance, lineage, and auditing in order to guarantee adherence to regulations.
2) *Advanced Analytics and Insights:* Contemporary data warehousing helps financial institutions make the most of cutting-edge analytics tools for actionable information. Data mining, predictive modeling, and machine learning are investigated for their potential use in analyzing consumer behavior, detecting fraud, determining credit risk, and optimizing business processes, among other areas.
3) *Decision Making and Processing in Real Time:* The advent of contemporary data warehousing has affected the speed and accuracy with which financial data can be processed in real time [8]. The article explains how financial institutions may take use of near real-time data to provide individualized suggestions, identify fraud in real time, and adapt rapidly to market shifts. This part also emphasizes the value of contemporary data warehousing in providing timely warnings and enabling proactive decision-making.
4) *Regulatory Compliance:* Data warehousing may assist financial institutions conform to rules and regulations. The importance of data governance, traceability, and auditability characteristics in achieving AML, KYC, and GDPR compliance is discussed. This section focuses on how contemporary data warehousing contributes to openness and responsibility in financial institutions.
5) *Customer Insights and Personalization:* Contemporary data warehousing helps financial institutions learn more about their clients and provide more tailored service. Data on customers from several sources, including as their demographics, purchase histories, internet activities, and social media interactions, are discussed. Customer happiness and loyalty are discussed, with special emphasis on the roles played by data-driven marketing efforts, individualized product suggestions, and exceptional customer experiences.

6) *Scalability and Cost Efficiency:* Data warehousing may help the banking sector save costs and increase scalability. It explains how banks may adjust their staffing levels in response to fluctuating workloads by employing cloud-based data warehousing systems. The possibility for saving money and doing away with costly preliminary expenditures in infrastructure are also discussed [12].

II. LITERATURE REVIEW

Muhammad Bilal Shahid et. All (2016) Data warehousing has been more popular in the corporate, financial, healthcare, and industrial worlds in recent years as a solution to the growing complexity and management challenges of today's data. Data warehousing is all about making information accessible for decision making, which is crucial given the necessity of gaining access to information stored in a knowledge-base. Modern decision support systems pivot on data warehouses. The design and execution of data warehouses in various applications are becoming more important as the need for them in the real world grows. This literature review discusses the uses of data warehouses in a wide range of settings, from the public sector to the nonprofit sector. The survey's literature overview and examples informed our study. According to the results of this research, non-profits are far more likely to use data warehouse technologies than government agencies. Data warehouses are mostly used by governments for anti-crime and anti-fraud purposes. Most NGOs rely on DW for data analysis, forecasting, and decision-making. [1]

Murnawan et. All (2021) Information is a valuable resource that managers use to formulate policies, execute plans, and settle on course of action. Data processing may take place in a number of different environments, including data warehouses, operational databases, and operational applications. The system data warehouse integrates disparate data sources for analysis of organizational performance and growth. The first step in this investigation is to do a database operational system analysis, which involves investigating the present software and hardware in use at PT XYZ. In order to improve the analysis process in decision making, such as the executive's ability to determine the company's strategy and predict its future needs, a data warehouse is designed to process detailed data originating from OLTP into data summaries. This is evident from the data structure, which takes the form of a multidimensional model represented by a star schema in a data warehouse and a database operationally specified by ERD in a running system. [2]

José Ferreira et. All (2017) In this article, authors take a look at how one financial services holding firm went about implementing a Data Warehouse and doing multidimensional analysis of their business data. The objective is to develop a business intelligence system that provides real-time access to aggregated, accurate, and forward-looking data on financial standings. Using Microsoft SQL Server's Integration Services and Analysis Services, the preexisting system retrieves and analyses the operational database data that underpins cash management data. The accomplished tasks proved that a DW method is a useful resource for decision-making on the strategic, tactical, and even operational levels of management. Microsoft SQL Server BI tools were used to put into effect the idea of constructing a DW mentioned in the literature study portion. OLAP cubes make it easier to access and examine massive datasets. Excel's PivotTable reports provide an overview of the summarized data, while the OLAP server does the computations. An intuitive UI makes it easy for users to do a wide variety of analyses (by month/year/bank/business type/real/estimated balance/etc.). Moreover, the process analysis becomes more automated and forgiving of user-introduced faults in the study of the process. These are the major benefits of this research that make up for the drawbacks of the past, when getting your hands on information and doing analyses took a long time and gave you little leeway. [3]

Aws Al-Okaily et. All (2022) In the era of business intelligence, it is crucial for practitioners and academics to be able to quantify the success or efficacy of data warehouse systems in order to fully grasp their personal and professional ramifications. Yet there have been little empirical studies evaluating its efficacy, either generally or specifically at the organizational level. In addition, different studies have employed different success variables, making it hard to generalize from the results. This study proposes and validates a model for gauging data warehouse efficacy, which consolidates insights into the essential success elements that influence the data warehouse's efficacy within the context of a business. This research adds to our knowledge of data warehouse efficiency by illuminating the connections between a variety of success variables such system quality, data quality, user happiness, and net system benefits (both personal and institutional). While the results of this research have theoretical and practical significance, they are not without caveats. The inability to broadly apply the findings is one such restriction. Since the setting of this study was Jordanian banks, our results may not apply to other industries and vice versa. Additional emerging nations and industries, such as the service and industrial ones, should be the focus of future efforts. Another weakness is that our study is cross-sectional in nature. Given the rapid evolution of both technology and business practices, it will be fascinating to see how future research measures the efficacy of data warehouses over time using longitudinal approaches. [4]

José Ferreira et. All (2017) Using an OLAP cube to get data proved to be more efficient than the holding company's prior strategy in both use cases, as demonstrated in the results section. In the first application, the t-value (2-tailored) for the significance level of 0.05 is greater than the t-value (0.05) for the difference between the means (OLAP cube vs. conventional approach). Consequently, this disparity is very statistically significant, suggesting that in use case I, an OLAP cube provides superior performance. This inference holds true in both the monthly and annual forecast scenarios.

In the second application, the t-value (2-tailored) for the significance level of 0.05 and 0.01% is greater than the hypothesis testing for the difference between the two means (OLAP cube vs. conventional technique). It follows that the OLAP cube provides superior performance, since this difference is also highly statistically significant. [5]

Donia Ali Hamed et. All (2019) Testing the Data Warehouse Environment may be done in a few different ways, including Data Quality Testing, Database Testing, and ETL Testing. Having confidence in the data's veracity for subsequent processing and decision making made testing the data crucial. Numerous strategies and instruments emerged to back and define the test cases to be utilized, their usefulness, and whether or not they might be automated. The most popular method was to use software to automate the testing of the data warehouse; initially, the tools only supported the automation of running the scripts, allowing developers to write the test case once and run it multiple times; later, however, the tools evolved to support the automation of creating the testing scripts as well, marketing their service as a comprehensive application that can handle both the creation and running of test cases. Data warehouses in the banking industry are completely unique from those in any other industry because they collect data from a wide variety of sources and locations, each of which may have its own unique data formats and quality standards. This data must then be transformed, loaded into the data warehouse, and partitioned into various data marts before it can be used in the various dashboards and projects that rely on it. [6]

Tanmaya Kumar Pattnaik (2012) Although operational data is the foundation for all BI tools, it is seldom presented in a way that helps with business decision making. Additionally, banks now store unprecedented amounts of data. For better and more timely decision-making, decision-makers need access to relevant data. More and more financial institutions are looking at methods to use their data assets to get an edge in the face of intensifying market rivalry and growing loan default rates. This paper examines the practical application of data warehouse applications to a wide range of banking industry business problems and shows how a bank-wide enterprise data warehouse can be set up to supply atomic level data on all banking transactions, customers, and products for use in decision-support applications. Finally, the introduction of technology like Data warehousing and Data mining tools can only improve the Indian banking environment. [7]

Veronika Stefanov et. All (2006) Data Warehouses (DWHs) are used by large businesses for performance analysis. The success of an organization is measured by how well it meets its objectives. The data models for DWHs are mature and reliable. There are many different ways to model different types of data. Formal or semiformal goal models are often used by businesses to represent their aims. In this research, we propose a method for business metadata that takes into account the connection between DWH information and organizational objectives. Information like as KPIs, target values, and the individuals and departments engaged in achieving these objectives are extracted from an enterprise model. By weaving together this organizational information with the DWH, we get the business metadata. The weaving model is then used to automatically generate the necessary business information. The weaving model aids in DWH requirements analysis, (re)design, and development by making context visible and accessible, which in turn enhances data interpretation by clarifying the data's relevance and context. An example of the method in action is shown. [8]

Diego Alex Harmatiuk et. All (2008) Online company structure A Data warehouse model's goal is to reflect the company in the model while also combining several facets of the firm's predetermined domain. Based on the findings, it is clear that the enterprise-based paradigm is crucial for achieving actionable outcomes quickly. When paired with business intelligence (BI) tools, these models provide a wealth of useful data upon which to base important decisions. This work paves the way for future research in data mining, with an emphasis on the definition of models as the domain of the data, and an analysis of the data in their natural state. The model determines the credibility of the data, and the credibility of the data ultimately determines the credibility of the information. They still plan to use the ideas discussed in the essay in the real world. The goal is to apply these principles to the healthcare sector by analyzing and comparing hospital models that are currently in use. [9]

Harry M. Sneed (2006) The need of a well-designed testing specification language was highlighted by this endeavor. When testing a web-based or online application, testers need to take on the roles of actual users. You can only automate so much. Since it is hard to predict every conceivable application of the technology, imaginative testing is crucial. The tester is often forced to wing it. As a result, testing by humans is crucial. A data warehouse test does not operate this way. Here, the challenge is to establish beyond reasonable doubt that everything in the data warehouse is accurate. This requires both a comprehensive specification of the contents and a comparison of the actual contents to the standards.

The difficulty is in designing a specification language that can support both objectives. After the mapping rules have been defined, testing and database validation are the responsibility of the tools. The tester's job is similar to that of an engineer overseeing a robotic assembly line, in that he or she observes the robots at work and intervenes only when necessary. To do this, he needs learn how the robots operate so that he may delegate tasks to them. This is the situation while testing a data warehouse. [10]

Kazi Imran Moin et. All (2012) With globalization and intense competition at every level, today's banks are fighting tooth and nail for whatever advantage they can acquire. The development of a knowledge base and its application to the bank's advantage are emerging as strategic tools for keeping up with the competition alongside the execution of business procedures. The capacity to produce, collect, and save data has grown immensely in recent years. There may be crucial insights hidden within these numbers. The IT sector is using data mining because of the widespread availability of large volumes of data and the need of turning such data into knowledge. Banking and retail businesses alike may benefit from data mining's ability to glean actionable insights from large amounts of raw data. In order to harvest useful information from large amounts of data, data warehousing brings together disparate datasets in a standard manner. After collecting data, it is evaluated and the results are utilized to guide business decisions. Banks may benefit greatly from Data Mining approaches in areas such as customer retention and relationship management, real-time fraud detection, product segmentation, and customer acquisition. Banks who have already begun implementing a data mining environment into their decision-making processes will gain a significant competitive edge in the future. [11]

M.Quafafou et. All (2005) OLAP analysis often relies on both the observed data and a collection of OLAP operators to reorganize and fine-tune the data. The objective is to unearth hidden patterns in data. Unfortunately, this method also stems from an analytical tradition. This later "hypothesis driven analysis" presupposes hypotheses based on the researcher's prior knowledge. By incorporating this information into the data warehouse, an analytical setting is created in which items and their relationships may be represented, managed, and viewed in greater detail. Authors look at a more in-depth integration, whereby operators of the foundational datawarehouse take into account both data and expertise. In this study, authors analyze web traffic using the same methods as a knowledge datawarehouse. This study examines the needs for a comprehensive integration of datawarehouses and knowledge discovery systems. Authors propose a datawarehouse paradigm and a three-tiered language that takes into account both information and expertise. Authors have shown a practical application that uses log files as input data. Using operators such as Select overloading, Multi-level approximation, and cell link identification and visualization, authors propose a log-file star schema for analysis. Using this method, authors have built a database specifically for patent research. This study is conducted within the framework of the Patent-OLAP project. Association rules are now integrated, and authors are also researching the integration of additional techniques of information extraction, including decision trees and probabilistic methods of rules induction. [12]

III. DW INITIATIVES AND MODELS FOR FINANCIAL ANALYSIS

The primary function of a DW is to provide historical information for management to use in making decisions. When one's challenging circumstance is unique compared to other known implementations, it might be difficult to put into practice. Decision makers' information demands (requirement-driven techniques) must be balanced with the data sources available to fill the DW (data-driven approaches). [6] After making the required adjustments, a middle ground between these two schools of thought emerges. This necessitates that management have faith in the data exploration capabilities, take into account large amounts of data (as in big data scenarios), or seek out a trustworthy and consistent method of information organization. A number of suggestions for multidimensional modeling and data warehouse architecture are also presented. However, it seems that no single approach to modeling and design has won out over a variety of others. Kamble's Conceptual Data Model for Data Warehouse suggests a standardized approach to modeling aggregations, data warehouse architecture, and multidimensional ideas. This paradigm has an impact on our work at the level of studies that, separately, investigate just a subset of the underlying issue. In reality, Kamble's models all use somewhat different approaches to organizing data. Authors found several studies using DW to address banking industry problems, as specified in our project's business domain analysis. [9] Studies using DW to connect a financial institution's banking operations appear to provide a novel challenging scenario, though. To counteract this obstacle, we investigate theoretical models that can motivate the development and widespread use of DWs.

A DW's structure is based on (i) facts and (ii) dimensions. Dimensions are used to analyze the outcomes of the metrics, and arithmetic operations (counting, summation, average, etc.) are used to tie the facts to the metrics of situations or occurrences.

In our example, the facts are the changes in bank accounts, and each fact has a monetary value and a value associated with the circumstance (debt or credit). Debt or credit may be used to total up the monetary values. Other dimensions, such as year balance, monthly balance, debts beyond a given amount, and credits from a specified business, may be acquired, however. Therefore, the worth of a motion is the link between the motion kinds and the constraint that selects among motions.

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Dimensional structuring of data is at the heart of this form of relationship. Future implementations of DWs will benefit from Schneider's model because of the unification of the concepts of fact and dimension it introduces. The fact that model representation is akin to the semantic web is also helpful. In the same way that Kamble's "Conceptual Data Model" uses the logic of the semantic web to address problems, this one does the same. Both have a same theoretical mathematical semantics based on traditional ER meaning.

IV. DATA WAREHOUSE ARCHITECTURE

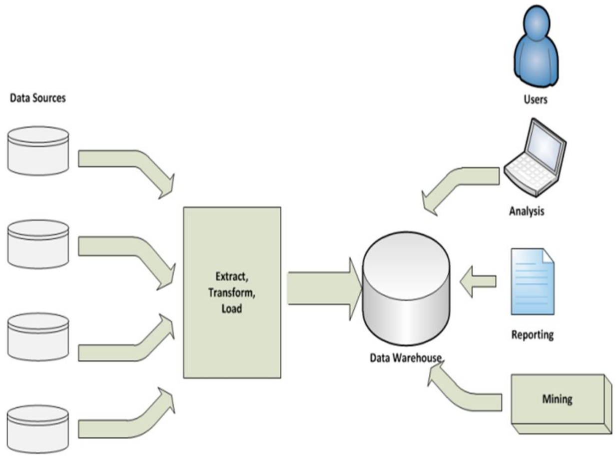

Figure: 1 Data Warehouse Architecture

Figure 1 provides an overarching perspective of data warehouse design applicable to all practical uses of a data warehouse. Extraction of informatics data from the primary system utilizing minimal resources, transformation of that data by applying a set of rules from source to destination, and fetching (loading) the associated data into a DW (called ETL process) are all essential steps in any data warehousing application. The technical design, the data design, and the hardware and software design are all areas where DW architecture shines. [5] The design space of DW architecture may be broadly classified as either enterprise DW design or design related to data marts. Combining these progressive data warehouses is what we call "enterprise DW." A data mart is similar to a DW in that it stores and organizes data, but its focus is on a narrower set of topics. Data marts use both top-down and bottom-up approaches to data design. There are many different types of DW designs, but the most common ones use some combination of an enterprise DW, "data marts," "distributed warehouses," and "operationally related" data rooms with data marts.

A. Scope of Modern Data Warehousing

Large amounts of data from contemporary sources like the cloud, social media, mobile devices, and the Internet of Things (IoT) must be stored, organized, and analyzed in a way that makes sense. This information is often kept in a data warehouse, which provides users with a consolidated view of all relevant data from which to draw conclusions and make choices.

Thanks to developments in data processing, storage, and analysis tools, the capabilities of contemporary data warehousing have grown substantially in recent years. Data from a variety of sources may be integrated because to the flexibility offered by modern data warehousing technologies, which can manage structured, semi-structured, and unstructured data.

Some of the most important components of contemporary data warehouses are:

1) *Scalability:* “Modern data warehouses can scale horizontally and vertically to accommodate large volumes of data and users.”
2) Cloud-based architecture: “Cloud-based data warehousing solutions provide organizations with a scalable and cost-effective way to store and analyze data.”
3) *Real-time data processing:* “Modern data warehouses can process data in real-time, enabling organizations to make real-time decisions.”
4) *Data integration:* “Modern data warehouses support data integration from a wide range of sources, including traditional databases, cloud-based applications, and IoT devices.”
5) *Data visualization:* “Modern data warehousing solutions offer advanced data visualization capabilities, making it easier for organizations to gain insights from their data” [13].

V. ISSUES MAY HAPPEN AND ANALYSIS

In banking environment critical issues may happen such as:

1) "Testing issues, covering all the test cases and checks for multiple projects and sources, which needs a huge effort and experienced resources and a lot of time".
2) "BI Issues, regarding the reconciliation of the dashboard statistics compared with the business team as there might be a gap on the results however, the ETL developed was completely correct".
3) "Operational issues, operation team that is responsible for running the daily flow of data for different sources and monitor the loading window of the projects faces loading issues as they might find the job ran on the integration tool successfully however zero records inserted or the job is taking too much time however the task has been already done or the session has been cancelled".
4) "Storage issues, as the huge load of amount of data from multiple sources that cannot be estimated suddenly becomes full, stopping all the flow on the server".
5) "Live projects that are up and running that business teams are completely depending on their results claiming that there was some codes missing or requested data not found which leads to losing the credibility of the project and its quality rather than its first initiation" [4].

VI. DATA WAREHOUSE DESIGN APPROACHES

There are two popular design schemas: Star schema and Snowflake schema.

Star schema - The subject area's principal fact table is denormalized in the star schema, and there are many dimension tables for describing the topic's dimensions. The number of rows in the fact table might be quite large. In order to further boost efficiency, frequently accessible data is generally preaggregated and summarized [2]. The Star schema may be seen of as a tool for the database administrator to improve efficiency and streamline data warehouse architecture, but it also provides a more intuitive representation of the data warehouse's contents for end users. Star schema has two major flaws:

Denormalization schema may require too much disk storage.

Very large dimension tables can adversely affect performance, partially offsetting benefits gained through aggregation.

Snowflake schema - The snowflake schema uses normalized dimension tables. Consider a deposit database with 200,000 transactions that spans 20 branches; this will help illustrate how disk storage may be used effectively. Each row in a star schema's equivalent dimensional schema would include data for all levels of the hierarchy above and including its own, making the total number of rows in the dimensional schema 200 thousand. In this scenario, it takes one hundred gigabytes of storage space to store one kilobyte of attribute data components. When this dimension table is normalized, no more space is required on the hard drive. The complexity of the normalized snowflake data structure is the biggest drawback of the snowflake (in comparison to the star). Furthermore, as the complexity of the data model increases, the total upkeep gets harder to maintain. One fact table and dimension tables for the Customer, Branch, Scheme [3], Transaction, and Time hierarchies are shown in Fig. 2 using a Snowflake architecture for an example Deposit DW.

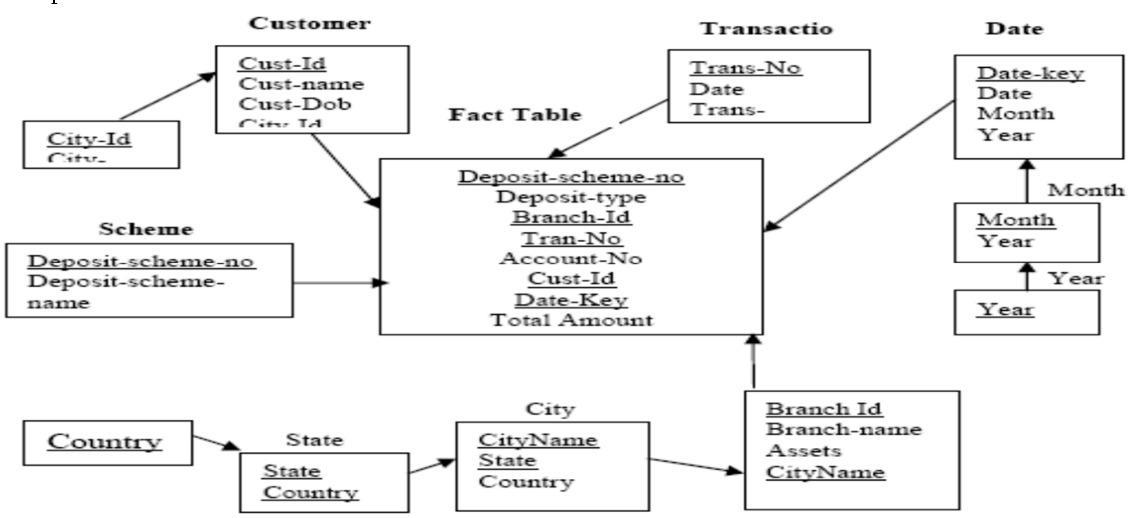

Figure: 2 Snowflake schema for a sample Deposit DW with one fact table

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VII. CHALLENGES ASSOCIATED WITH MODERN DATA WAREHOUSING IN BANKING SECTOR

The banking industry may greatly benefit from contemporary data warehousing, but it also offers several problems that must be overcome. Key difficulties of contemporary financial data warehousing include the following:

1) Data Security and Privacy: Since banks handle such private information, they prioritize protecting it. The danger of data breaches and unauthorized access is elevated in modern data warehousing due to the aggregation of massive volumes of data from many sources. [1] To safeguard customer information and stay in line with regulations, banks must use stringent security measures including encryption, access limits, and frequent security audits.
2) Data Integration and Quality: Integrating data from many systems, services, and suppliers is a crucial aspect of today's data warehouses. Disparities in data formats, structures, and quality may make data integration a difficult task. Erroneous conclusions and actions may result from using incomplete or inaccurate information. To maintain the trustworthiness and integrity of the data warehouse, banks must invest in data integration technologies, data cleaning procedures, and data quality monitoring.
3) Scalability and Performance: As the amount of data generated and processed by banks continues to expand at an exponential pace, scalability becomes more difficult. High-performance, near real-time analytics on massive amounts of data are a must for today's data warehouses. To keep up with the changing needs of the banking industry, it is essential to ensure that the data warehouse architecture can grow without compromising performance.
4) Governance and Compliance: There are several privacy, security, and regulatory standards that financial institutions must meet. The data governance, lineage, and auditability requirements of a modern data warehouse are more involved. To achieve regulatory compliance and preserve transparency, banks must build strong governance structures, implement suitable data access rules, and record the full history of all relevant data.
5) Skillset and Talent: Modern data warehousing systems demand specific skills and knowledge to implement and manage effectively. To stay competitive, financial institutions need staff with expertise in data modeling, data integration, analytics, and cloud computing. As the need for data-driven knowledge increases, it may be difficult to find and keep good data experts. [11] To make the most of today's data warehousing tools, financial institutions must invest in training programs and compete for the best people in the industry.
6) Legacy System Integration: Many financial institutions still use antiquated systems and software that are not compatible with today's data warehousing tools. Data integration from legacy systems is often challenging and time-consuming due to the need for careful planning of data mapping, transformation, and compatibility. If financial institutions want to guarantee smooth data flow and integration, they must either modernize their old systems or devise techniques to combine them with current data warehousing infrastructure.
7) Cost Considerations: Even while contemporary data warehousing saves money in comparison to on-premises solutions, it still requires investment in things like hardware, software, space, and upkeep [7]. To guarantee that the advantages received from modern data warehousing balance the expenditures spent, banks need to carefully examine the total cost of ownership and create cost control techniques.

Data governance frameworks, security measures, experienced people, and well-defined data integration procedures are all essential for effectively addressing these issues.

The banking industry may benefit greatly from data-driven decision making, customer-centricity, and operational efficiency if these obstacles can be overcome.

VIII. CONCLUSION

The paper's results are summed up in the conclusion, with an emphasis on how contemporary data warehousing has had a profound effect on the banking sector. Data management, sophisticated analytics, real-time processing, regulatory compliance, customer experience, and cost efficiency are all areas that might see significant improvements as a result of this. Future research initiatives and the changing function of data warehousing in the financial sector are also discussed.

The accomplished tasks proved that a DW method is a useful resource for decision-making on the strategic, tactical, and even operational levels of management.

In conclusion, this review paper offers a thorough examination of how contemporary data warehousing is Impact on the banking sector. Impact areas are highlighted, and the advantages and disadvantages of employing current data warehousing technologies are discussed. This review's results help illuminate how data warehousing has propelled the digital transformation of the banking sector.

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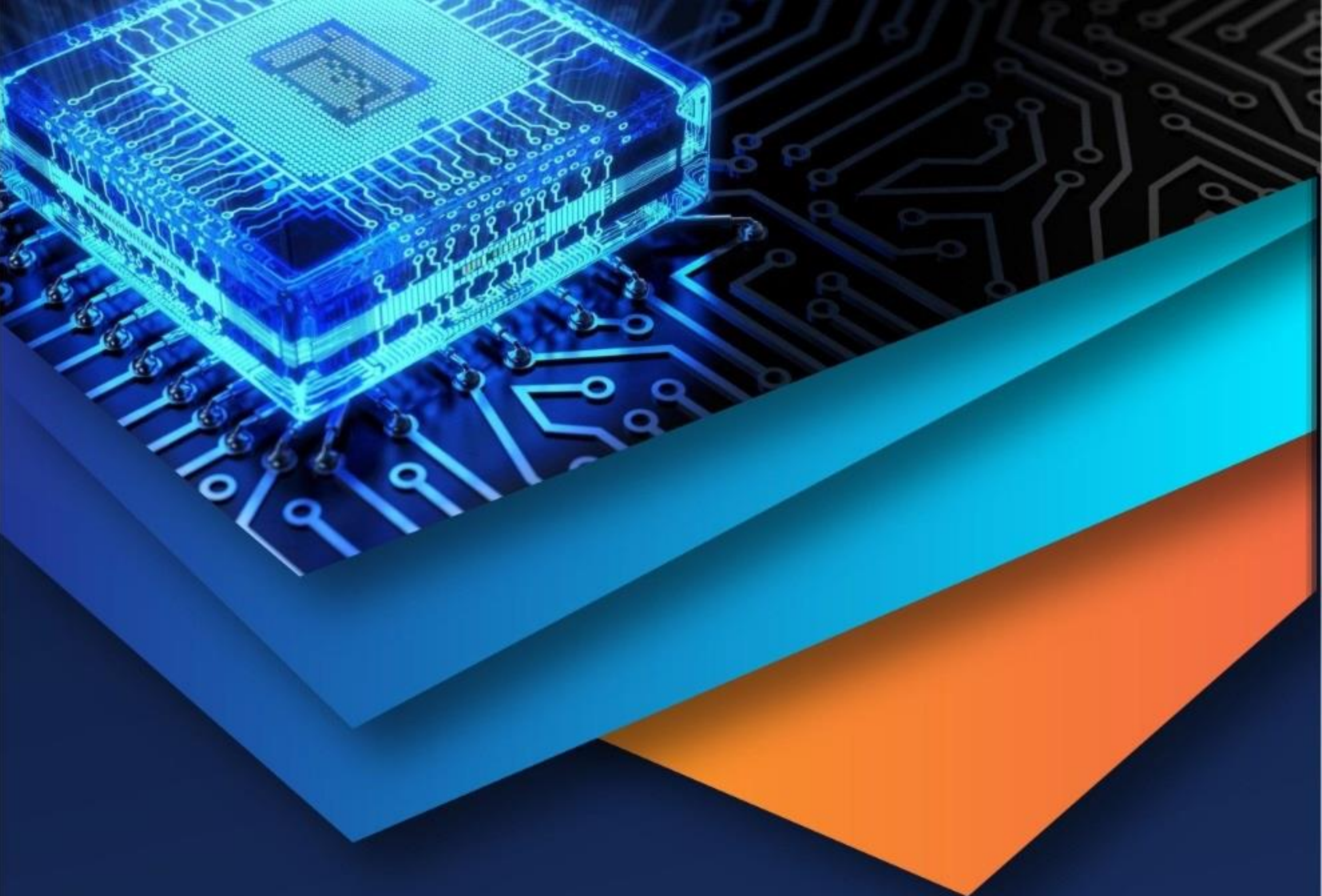

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