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Big Data in Banking

Matthew N. O. Sadiku[1], Paul A. Adekunte[2], Janet O. Sadiku[3]

[1]Roy G. Perry College of Engineering, Prairie View A&M University, Prairie View, TX, USA
[2]International Institute of Professional Security, Lagos, Nigeria
[3]Juliana King University, Houston, TX, USA

ABSTRACT

Big data has become one of the most important resources in modern banking. Banks generate and receive enormous volumes of information from card payments, mobile applications, online transfers, credit applications, customer-service interactions, market feeds, and regulatory reports. Big data refers not merely to a large quantity of records, but to data environments whose volume, velocity, and variety require advanced storage, processing, and analytical methods. Big data in banking is the large-scale integration and analysis of transactional, behavioral, financial, demographic, operational, and external information to improve decisions, automate processes, control risk, and create customer value. The importance of big data therefore lies in its conversion of raw information into timely decisions. From processing millions of daily transactions to predicting customer needs, big data analytics is transforming the banking sector into a data-driven powerhouse. In this paper, we will explore what big data analytics in banking really means, explore its applications, benefits, and challenges.

KEYWORDS: *big data, big data analytics, banking, banker, banking industry.*

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INTRODUCTION

The banking industry has always depended on information. Banks record deposits, withdrawals, transfers, loans, repayments, and investments while also collecting information about customers, markets, and economic conditions. Digital banking has greatly expanded both the volume and the diversity of this information. Big data in banking refers not merely to possessing large databases but to collecting, combining, and analyzing extensive, rapidly generated, and varied information to produce useful insights. These data may be structured, such as account balances and transaction records; semi-structured, such as application forms and system logs; or unstructured, such as emails, call transcripts, and customer feedback. When supported by technologies such as cloud computing, machine learning, and real-time analytics, big data can improve banking decisions [1].

WHAT IS BIG DATA?

Big data applies to data sets of extreme size (e.g. exabytes, zettabytes) which are beyond the capability of the commonly used software tools. It involves situation where very large data sets are big in volume, velocity, veracity, and variability [2]. The data is too big, too fast, or does not fit the regular database architecture. It may require different strategies and tools for profiling, measurement, assessment, and processing. The cloud word for big data is shown in Figure 1 [3].

Big Data is essentially classified into three types [4]:

- *Structured Data:* This is highly organized and is the easiest to work with. Any data that can be stored, accessed, and processed in the form of fixed format is known as a structured data. It may be stored in tabular format. Due to their nature, it is easy for programs to sort through and collect data. Structured data has quantitative data such as age, contact, address, billing, expenses, credit card numbers, etc. Data that is stored in a relational database management system is an example of structured data.
- *Unstructured Data:* This refers to unorganized data such as video files, log files, audio files, and image files. Any data with unknown form or the structure is classified as unstructured data. Almost

everything generated by a computer is unstructured data. It takes a lot of time and effort required to make unstructured data readable. Examples of unstructured data include Metadata, Twitter tweets, and other social media posts.

- *Semi-structured Data:* This falls somewhere between structured data and unstructured data, i.e., both forms of data are present. Semi-structured data can be inherited such as location, time, email address, or device ID stamp.

The different types of big data are depicted in Figure 2 [5].

The process of examining big data is often referred to big data analytics. It is an emerging field since massive computing capabilities have been made available by e-infrastructures [6]. Big data analytics is the application of advanced analytic techniques to large, heterogeneous data sets that comprise structured, semi-structured, and unstructured data from many sources with sizes ranging from terabytes to zettabytes.

Analytics include statistical models and other methods that are aimed at creating empirical predictions. Data-driven organizations use analytics to guide decisions at all levels. Several techniques have been proposed for analyzing big data. These include the HACE theorem, cloud computing, Hadoop, and MapReduce [7].

CHARACTERISTICS OF BIG DATA

Big data is growing rapidly and expanding in all science and engineering, including physical, biological, and medical services. Different companies use different means to maintain their big data. As shown in Figure 3 [8], big data is characterized by 42 Vs. The first five Vs are volume, velocity, variety, veracity, and value.

- *Volume*: This refers to the size of the data being generated both inside and outside organizations and is increasing annually. Some regard big data as data over one petabyte in volume.

- *Velocity*: This depicts the unprecedented speed at which data are generated by Internet users, mobile users, social media, etc. Data are generated and processed in a fast way to extract useful, relevant information. Big data could be analyzed in real time, and it has movement and velocity.

- *Variety*: This refers to the data types since big data may originate from heterogeneous sources and is in different formats (e.g., videos, images, audio, text, logs). BD comprises of structured, semi-structured or unstructured data.

- *Veracity*: By this, we mean the truthfulness of data, i.e. weather the data comes from a reputable, trustworthy, authentic, and accountable source. It suggests the inconsistency in the quality of different sources of big data. The data may not be 100% correct.

- *Value*: This is the most important aspect of the big data. It is the desired outcome of big data processing. It refers to the process of discovering hidden values from large datasets. It denotes the value derived from the analysis of the existing data. If one cannot extract some business value from the data, there is no use managing and storing it.

On this basis, small data can be regarded as having low volume, low velocity, low variety, low veracity, and low value. Additional five Vs has been added [9]:

- *Validity:* This refers to the accuracy and correctness of data. It also indicates how up to date it is.

- *Viability:* This identifies the relevancy of data for each use case. Relevancy of data is required to maintain the desired and accurate outcome through analytical and predictive measures.

- *Volatility:* Since data are generated and change at a rapid rate, volatility determines how quickly data change.

- *Vulnerability:* The vulnerability of data is essential because privacy and security are of utmost importance for personal data.

- *Visualization:* Data needs to be presented unambiguously and attractively to the user. Proper visualization of large and complex clinical reports helps in finding valuable insights.

Instead of the 10V's above, some suggest the following 5V's: Venue, Variability, Vocabulary, Vagueness, and Validity) [9].

Industries that benefit from big data include the healthcare, financial, airline, travel, restaurants, automobile, sports, agriculture, and hospitality industries. Big data technologies are playing an essential role in farming: machines are equipped with sensors that measure data in their environment. Structured and unstructured data are generated in various types [10-13].

BIG DATA IN BANKING

The digital revolution has ushered in an age where data is not just an asset but the lifeblood of financial institutions. In banking, big data encompasses high-volume, high-velocity, and high-variety information generated across core banking systems, payment networks, digital channels, trading platforms, risk engines, and regulatory reporting. Globally, several quintillion bytes of data are produced daily, with financial institutions among the largest contributors due to transactional intensity, continuous market activity, and compliance requirements. Unlike in less regulated industries, financial data is inseparable from accountability and traceability. Every transaction, balance movement, or risk calculation must be reproducible, auditable, and explainable to internal stakeholders and regulators. Banking data is closely linked to financial and regulatory risk. Errors or delays can result in capital misallocation, regulatory breaches, or financial loss. In an industry where speed, accuracy, and trust are everything, the ability to act on data intelligently has become one of the most powerful competitive advantages a bank can have [14]. Figure 4 shows a representation of big data in banking [15].

Big data delivers measurable value only when it functions as a decision infrastructure—an integrated system where data, analytics, and governance support operational, risk, and compliance decisions. In banking, big data creates value when it improves the quality, speed, or reliability of decisions integrated in core operations. However, progress within banking is relative—many companies have yet to realize the full potential from embedding analytics deep into their culture, decision processes, and business operations [16].

Big data analytics is a valuable part of a modern strategy. It enables businesses to build and analyze detailed customer profiles to deliver more personalized products. The effective use of data analytics helps banks to move from traditional decision-making methods, which often rely on historical data and intuition, to data-driven strategies that enhance operation accuracy and speed. Big data analytics helps banks reduce compliance risks, stay prepared for regulatory reviews, and respond faster to changing financial requirements. The bank also relies on big data analytics for credit scoring, fraud detection, risk management, personalized recommendations, and compliance alignment. Real-time analytics is especially essential for banks to detect fraud, manage risk, and make faster, data-driven decisions. Today, banks are shifting to real-time analytics systems capable of continuously processing streaming data from transactions, mobile applications, and other sources [17]. Figure 5 shows big data and analytics in banking [18].

APPLICATIONS OF BIG DATA IN BANKING

There are a lot of big data use cases in banking; some of the common ones include customer segmentation and profiling, personalization, risk management and credit scoring, fraud detection and prevention, predictive analytics, predictive maintenance, regulatory compliance, credit assessment, and operational forecasting. Figure 6 shows some applications of big data analytics in banking [19]. Common applications of big data in banking include the following [1,17,20,21]:

- *Customer Segmentation*: It is essential to know and understand who your customers are to effectively meet their needs. Big data helps banks gather diverse information about their customers and use it to create highly accurate customer portraits and offer tailored services. Effective customer segmentation offers banks several advantages.
- *Risk Management*: Risk management is another major field of application. Banks can analyze loan portfolios at a granular level to estimate default probabilities, loss severity, sector concentration, geographic exposure, and sensitivity to changing economic conditions. By integrating internal account data with market prices, interest rates, news, supply-chain information, and macroeconomic indicators, institutions can update risk assessments more frequently than under periodic, spreadsheet-based approaches.
- *Credit-risk Assessment*: One of the most important applications of big data is credit-risk assessment. Traditional lending decisions often rely on a limited set of variables, including income, employment, existing debt, collateral, and credit history. Big data analytics can supplement these indicators with broader patterns derived from transaction histories, repayment behavior, cash-flow movements, and other relevant information. These additional signals may help a bank estimate the probability of default more accurately and make quicker lending decisions.
- *Fraud Detection*: One of the most valuable applications of big data is the detection of fraudulent transactions. Big data and statistical computing empower banks to detect potential fraud before it even occurs. Because digital transactions can occur almost instantly, a bank must identify suspicious activity quickly enough to prevent or limit losses. Analytical systems can compare a transaction with a customer's normal behavior and search for unusual combinations of location, device, amount, timing, merchant, or transfer pattern. Machine-learning systems may detect relationships that fixed rules overlook, while network analysis can reveal connections

among accounts involved in organized fraud or money laundering.

- *Anti-Money Laundering*: Banks must continuously monitor large numbers of customers and transactions for money laundering, terrorist financing, sanctions violations, tax evasion, and other illicit activity. This task naturally lends itself to big-data analysis. Modern monitoring systems can integrate customer identity records, beneficial-ownership information, sanctions lists, payment messages, geographic risk, counterparty relationships, and historical alerts. Natural language processing can extract information from corporate filings and unstructured documents, while graph analytics can expose hidden relationships among accounts and entities.
- *Personalization:* Big data supports customer service personalization. By combining information from branches, websites, mobile applications, call centers, and product usage, a bank can develop a more complete understanding of customer needs. Analytics may help identify customers who are likely to need a savings product, a working capital loan, or assistance following a change in financial circumstances. Digital assistants can use account information to answer routine questions, and customer-feedback analysis can reveal recurring service problems. Used responsibly, personalization can make banking more convenient and relevant.
- *Operational Management*: A further application is operational management. Banks can analyze internal workflows to detect delays, predict transaction volumes, allocate staff, manage cash requirements, and identify system weaknesses. Real-time information can improve liquidity monitoring and enable faster responses to changing market conditions. Data from information technology systems may also help predict equipment failures or service interruptions before they affect customers.
- *Customer Profiling:* Big data plays a crucial role in customer profiling within banking institutions. Banks can offer individualized plans and financial data solutions by analyzing a customer's banking history and personal and transactional information, and monitoring customer spending patterns over time. This enhances the customer experience and enables banks to differentiate their services, increasing customer retention. Additionally, banks can target specific products to customers based on demographic data.
- *Customer Segmentation*: With machine learning (ML) and AI, big data analytics allows for effective customer segmentation. Banks can accommodate big data analytics and categorize their customers based on multiple parameters, such as credit card expenditures or net worth. This enables targeted marketing campaigns that resonate more closely with the individual customer needs.
- *Predictive Maintenance*: Big data is one of those vital tools needed for catching potential issues before they blow up. Banks can predict when maintenance is needed before breakdowns occur by analyzing usage patterns and performance data from ATMs and other banking equipment. This allows banks to implement preventative measures, schedule maintenance during off-peak hours, and ensure backup systems are in place.
- *Data Storage*: Data storage is a digital place to store and manage data, as well as transform unstructured data into a format suitable for use by analytical tools. Modern big data architectures typically rely on data lakes and data warehouses to store different types of information. An analytical data store is a customized database or data storage system located between data processing and analytics. It is designed to store processed and cleaned data, making it accessible for use with different analytical techniques and BI tools. It is vital for further analysis and reporting. The key features of analytical data stores in big data analytics are column storage, optimized query processing, data integration, support for advanced data analytics, data governance, and security.

BENEFITS

The principal benefits of big data in banking are stronger decision-making, more accurate risk management, improved security, personalized customer service, greater operational efficiency, more effective regulatory compliance, wider financial inclusion, better strategic decisions, more accurate credit assessment, earlier fraud detection, personalized services, lower operating costs, stronger compliance, and broader access to finance. Other benefits of big data in banking include the following [1,14]:

- *Operational Efficiency*: Big data can also produce significant operational efficiencies. Big data methods can reveal inefficiencies within the bank itself. Process-mining tools analyze time-stamped workflow records to identify bottlenecks in account opening, loan approval, dispute resolution, and back-office settlement. Call center analytics can classify customer concerns, measure sentiment, predict demand, and identify recurring service failures. Forecasting models improve workforce scheduling, cash replenishment for automated teller machines, branch capacity planning, and technology-resource allocation.

- *Better Decision-making*: One of the greatest benefits of big data is better decision-making. Traditional banking decisions often depend on periodic reports, limited samples, or historical records that may become outdated before managers can act on them. Big data systems can process information from numerous sources much more quickly, allowing banks to monitor business conditions, customer behavior, and emerging risks with greater timeliness. Although central banks are different from commercial banks, this evidence demonstrates the broader value of timely, data-driven analysis across the financial system. For an individual bank, such analysis can improve decisions about lending, liquidity, pricing, branch strategy, and resource allocation.
- *Improved Decision Quality*: The most direct benefit of big data is improved decision quality. A bank that can integrate accurate information from multiple sources may obtain a more complete picture of a borrower, transaction, or risk exposure than one relying on isolated records. Better analysis can reduce uncertainty, improve pricing, and direct human attention toward the cases that require it most. Automation can also shorten processes that once required extensive manual work, lowering costs and allowing staff to focus on complex decisions, relationship management, and exception handling.
- *Financial Inclusion:* Big data may improve financial inclusion when it reduces information asymmetry. Customers and small businesses without long formal credit histories can be difficult to assess through conventional scoring methods. With suitable safeguards, verified cash-flow and payment information may provide evidence of repayment capacity that a traditional credit file does not contain. The World Bank notes that big data can support the expansion and improvement of financial services, while recent scholarship connects customer-behavior analytics with the development of more inclusive products.
- *Personalization*: Big data will also make banking more individualized. Current personalization often consists of broad product recommendations based on demographic categories or prior purchases. Future systems will combine cash-flow patterns, savings goals, credit obligations, life events, channel preferences, and real-time context to produce more relevant services. A bank could warn a customer of a probable cash shortfall, automatically propose a suitable repayment plan, identify an unused subscription, or adjust savings recommendations as income and expenses change. However, personalization can easily become intrusive. The same data used to provide timely assistance can be used to manipulate behavior, discriminate among customers, or make opaque judgments about their reliability.

Figure 7 displays some benefits of big data in banking [22].

CHALLENGES

Big data offers banks major opportunities, but it also magnifies familiar weaknesses in information management and creates new forms of technological, ethical, and regulatory risk. The same characteristics that make big data valuable also make it dangerous when poorly controlled. The principal challenges include poor data quality, fragmented systems, privacy and cybersecurity exposure, complex legal obligations, algorithmic bias, limited explainability, skills shortages, high costs, and threats to operational resilience. Other challenges of big data in banking include the following [1,22]:

- *Cost*: Cost is a major obstacle. Data platforms require storage, computing capacity, specialist software, integration work, quality management, security, model validation, and continuous maintenance. The expense does not end when a system is launched. Data distributions change, software becomes obsolete, threats evolve, and regulatory expectations develop. Banks must monitor analytical pipelines and models continuously, test recovery arrangements, and retain the ability to operate when data or services become unavailable.
- *Privacy*: Privacy is a primary concern because banking information can reveal income, health-related payments, travel, relationships, habits, and personal difficulties. Banks must limit collection to legitimate purposes, obtain valid permissions where required, protect data throughout its life cycle, and avoid secondary uses that customers would not reasonably expect. Customers may not understand how extensively their information is being combined or how automated inferences affect them. A data breach can expose highly sensitive records, while excessive retention increases the damage that a security failure may cause. Banks therefore need strong access controls, encryption, monitoring, retention limits, and clear rules governing both internal use and third-party access.

- *Data Quality:* Data quality presents another challenge. Poor data quality can lead to incorrect analysis, which in turn can result in flawed decision-making. Ensuring the data's quality, management, and integrity is a constant challenge. Analyzing big data often requires rigorous validation and cleaning processes. Poor quality or unrepresentative information can generate unreliable conclusions, and opaque algorithms can reproduce historical bias. Duplicate identities, missing fields, inconsistent definitions, stale records, and biased samples can generate unreliable conclusions at scale. Complex models may also be difficult to explain, audit, or challenge. Weak data quality is especially dangerous in banking because analytical outputs influence high-stakes decisions. Errors can distort credit assessments, conceal concentrations of risk, generate false fraud alerts, or undermine regulatory reports.
- *Bias:* Bias and lack of explainability present another major challenge. An algorithm trained on historical decisions may reproduce earlier discrimination even if protected characteristics are removed, because other variables can act as proxies. Complex models may also make it difficult for employees, customers, auditors, or regulators to understand why a decision was reached. This is particularly serious when an automated result affects access to credit or other essential financial services. The European Banking Authority identifies fairness, avoidance of bias, explainability, traceability, data protection, data quality, security, ethics, and consumer protection as central elements of trust in big-data and advanced-analytics systems.
- *Risks:* Banks must also manage model risk: the possibility that an analytical model is incorrect, misused, or no longer suitable because conditions have changed. A model that performed well during stable economic conditions may fail during a crisis, and fraud patterns may evolve after criminals learn how monitoring systems operate. Banks need independent review, documentation, performance monitoring, controlled changes, escalation procedures, and meaningful human authority to challenge automated outputs.
- *Governance:* Governance is difficult because data cross organizational boundaries. Business units may treat information as a local asset, while technology teams manage storage and access, risk functions question model outputs, and compliance teams enforce restrictions on use. Without clearly assigned accountability, problems remain unresolved between departments. Banks must therefore establish who owns each important data set, who may alter it, which uses are permissible, and how quality exceptions are corrected. Such governance can be expensive and slow, but without it the speed of analytics merely accelerates unreliable decision making.
- *Legacy Systems*: Another challenge is the coexistence of big data platforms with legacy banking infrastructure. Many banks operate long-established core systems designed for reliable transaction processing rather than flexible, real-time analytics. Data may be divided across mainframes, departmental databases, acquired institutions, cloud services, and third-party platforms. Integrating these environments requires complex interfaces and extensive data transformation. As a result, banks may create new analytical systems while leaving the underlying fragmentation largely intact. This technical complexity produces several risks.
- *Cybersecurity*: Finance is the second-most targeted sector for cyberattacks globally. Big data also creates a serious privacy and cybersecurity challenge. Banking is highly regulated, and big data initiatives must operate within rules governing privacy, cybersecurity, consumer protection, record retention, outsourcing, reporting, and model risk. The concentration of sensitive information also makes banking systems attractive targets for criminals and other adversaries. Security must consequently extend across the complete data life cycle. Protection is required when data are collected, transmitted, stored, analyzed, shared, archived, and deleted. Encryption and access controls are important, but technical safeguards alone are insufficient. Banks also need monitoring, segregation of duties, third-party oversight, employee training, incident-response procedures, and tested recovery plans.
- *Explainability*: Explainability creates a further tension. Highly complex models may improve predictive performance but make it difficult for employees, customers, auditors, and supervisors to understand why a particular decision occurred. A bank must often do more than show that a model is accurate on average; it must demonstrate that the system is appropriate, monitored, and subject to human accountability. Banks therefore need model documentation, independent validation, performance monitoring, bias testing, controlled overrides, and procedures for challenging automated outcomes.

- *Skills Shortage*: Big-data banking requires professionals who understand statistics, software engineering, cybersecurity, banking products, regulation, and ethics. Such combinations of expertise are scarce, and communication between specialists can be difficult. A technically strong model may fail because its creators misunderstand lending policy, while a conservative control function may block useful innovation because it cannot evaluate the technology.
- *Cultural Resistance:* Implementing big data strategies often requires a shift in the organization's mindset, which can lead to some hesitation among team members.

To ease this transition, banks can cultivate a culture that values data-driven insights and encourages openness to new approaches. Hosting data workshops and highlighting the benefits of big data can create an environment where change is embraced. This way, everyone feels more comfortable adapting to innovative practices and the transition gets smoother and more collaborative.

Figure 8 displays some key challenges of big data in banking [18].

FUTURE OF BIG DATA IN BANKING

Big data has already changed banking, but its most important effects are still ahead. In the coming years, big data analytics will become more closely connected with artificial intelligence, open-banking systems, real-time payments, and automated customer service. Banks will increasingly analyze information as events occur rather than waiting for periodic reports. The future should not be understood as a simple movement toward fully automated banking. Instead, successful institutions are likely to combine machine speed with human accountability.

The future of big data in banking will therefore depend less on how much information banks can collect than on how responsibly they can use it. Institutions that combine analytical sophistication with explainability, fairness, security, human oversight, and strong data governance will be best positioned to gain the benefits of big data while preserving the trust on which banking ultimately depends. The strongest institutions will not necessarily be those that collect the most data. They will be those that can use data selectively and responsibly while preserving accuracy, fairness, compliance, and customer trust.

The future of big data is particularly significant for lending. Conventional credit systems frequently depend on formal borrowing histories, audited statements, collateral, and standardized credit files. The future of big data in banking is not a future in which more information automatically produces better finance. It is a future in which competitive advantage depends on turning data into trustworthy action. Future credit analytics will consequently be judged by more than predictive performance. Banks will need to test outcomes across customer groups, document data lineage, monitor drift, limit irrelevant variables, and preserve a route for human review. Future banks will therefore require enterprise-wide systems for defining, cataloguing, and tracing data. Big data will alter jobs across banking, but the effect will be more complex than simple replacement [1].

CONCLUSION

Big data is making waves across industries and banking is no different. It is reshaping banking by turning continuous streams of information into decisions about fraud, credit, customers, risk, compliance, and operations. Its most important applications include real-time anomaly detection, more precise credit assessment, personalized service, liquidity forecasting, anti-money-laundering analysis, and process automation.

Big data enables banks to understand risks, customers, transactions, and internal processes with greater speed and depth. The central issue is not whether banks should use big data, but how they should use it. Responsible adoption requires high-quality information, secure infrastructure, clear accountability, explainable methods, rigorous model validation, and meaningful protection for customers. The central argument of this work is that big data will become the operating foundation of banking rather than a specialized analytical resource. More information about big data in banking can be found in the books in [23-27] and the following related journal: *Journal of Big Data.*

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Figure 1 The cloud word for big data [3].

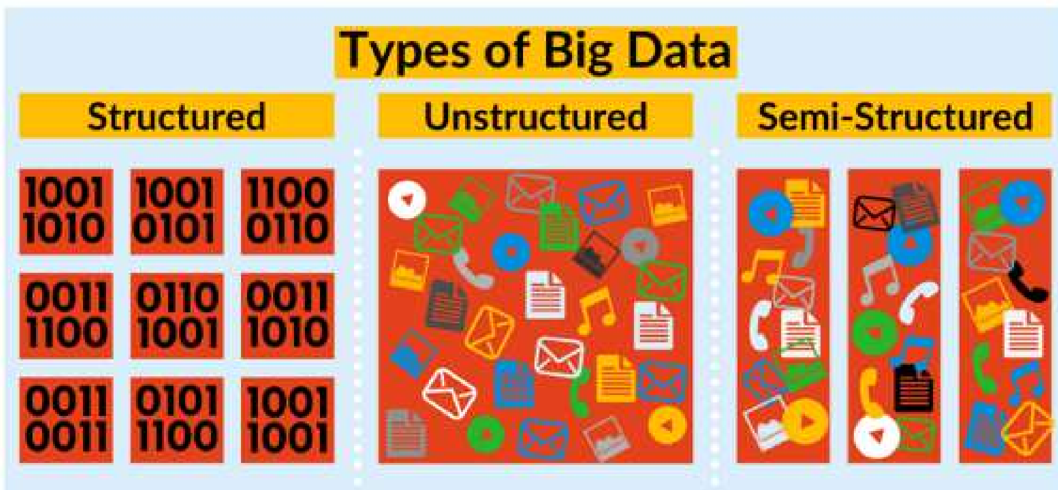

Figure 2 Types of big data [5].

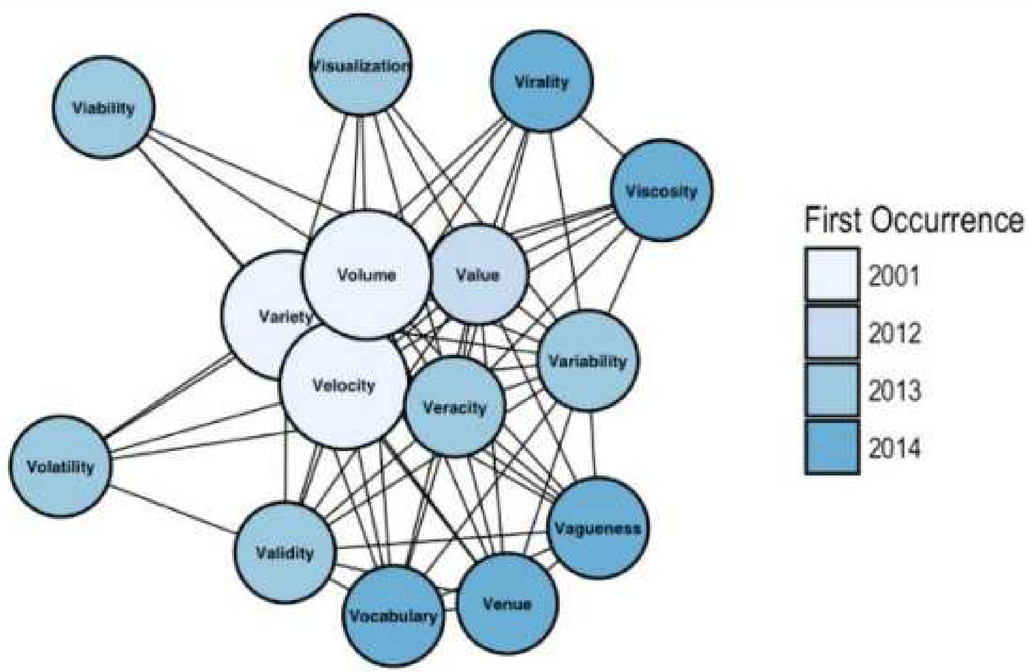

Figure 3 The 42 V's of big data [8].

Figure 4 A representation of big data in banking [15].

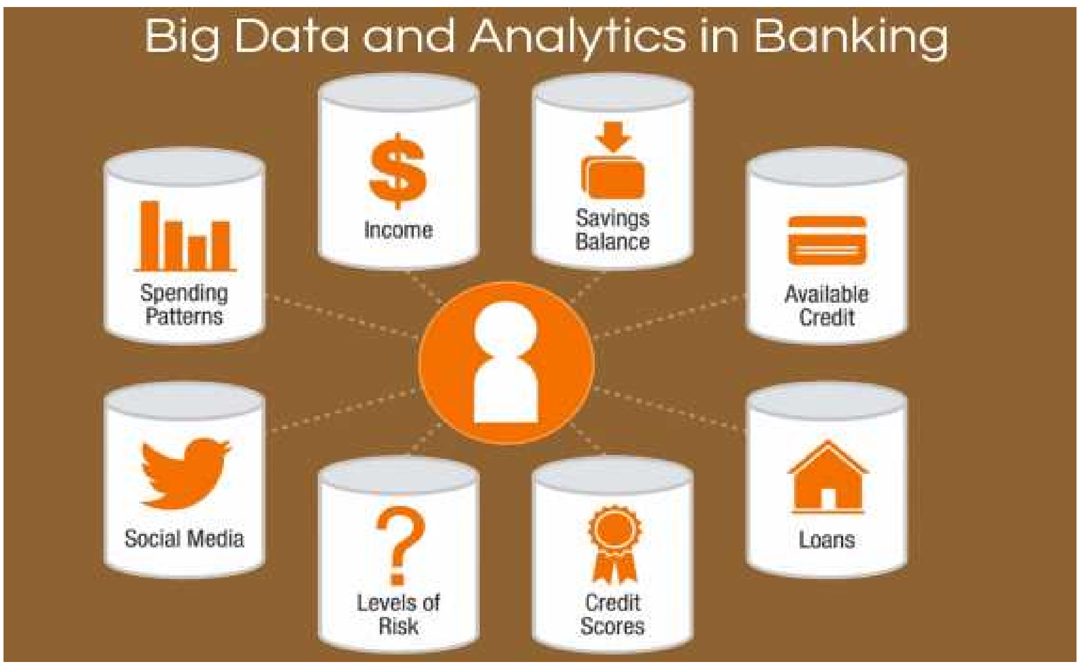

Figure 5 Big data and analytics in banking [18].

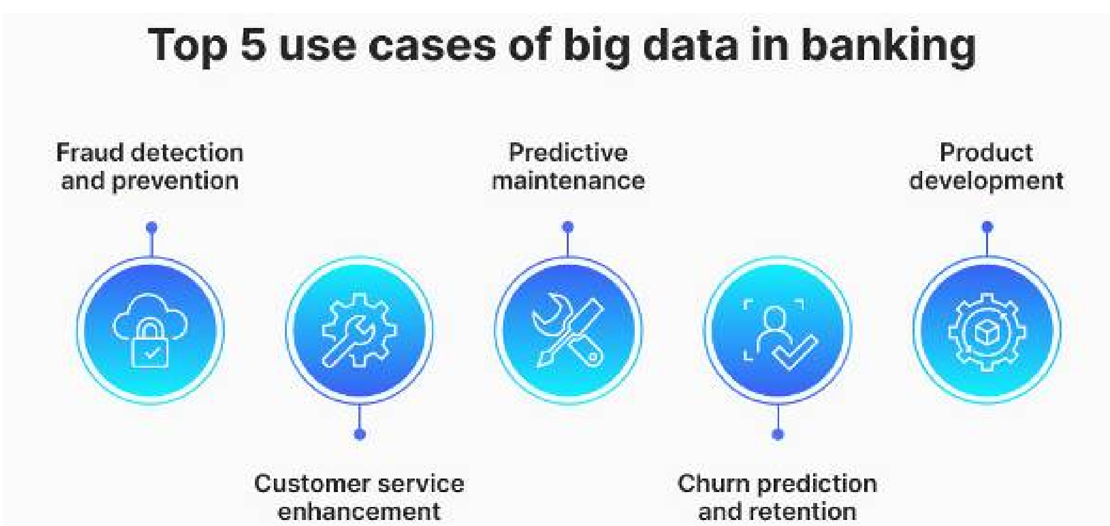

Figure 6 Some applications of big data analytics in banking [19].

Figure 7 Some benefits of big data in banking [22].

Figure 8 Some key challenges of big data in banking [18], p.110.