VILNIUS UNIVERSITY
BUSINESS SCHOOL

DEEP TECH ENTREPRENEURSHIP

Ugnius Eirikas

MASTER THESIS

Dirbtinis intelektas ir debesų kompiuterijos inovacijos bankininkystėje: aukštųjų technologijų požiūris į pagrindinių finansinių operacijų optimizavimą	AI and Cloud Innovation in Banking: A Deep-Tech Approach to Optimizing Core Financial Operations

Supervisor

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Summary

The rapid development of artificial intelligence and cloud computing is reshaping the banking sector and enabling significant improvements in operational efficiency, risk management, and service quality. However, despite their potential, banks continue to face difficulties integrating these technologies into core financial operations due to regulatory constraints, legacy systems, security requirements, and limited specialised expertise. While scientific literature highlights the benefits of AI and cloud technologies, it lacks a unified methodology for evaluating their integration in banking, which defines the scientific problem of this thesis.

The object of the research is the qualitative evaluation of AI and cloud innovations in core banking operations. The aim is to develop qualitative criteria for assessing the effectiveness of AI and cloud adoption and to propose a model for applying these criteria.

The study applies a qualitative research methodology. Data were collected through structured questionnaires completed by eight experts representing technological and operational banking roles. The research uses literature analysis, thematic analysis to ensure the consistency of expert assessments. Case studies of international banks supplement expert insights.

The research identified six qualitative criteria that reflect the effectiveness of AI and cloud integration: operational efficiency, scalability, risk and compliance, cybersecurity, customer experience, and innovation capacity. Barriers and success factors were also identified. Based on these insights, a model for applying qualitative criteria was developed, offering banks a structured approach for evaluating technological maturity and planning deep-tech integration.

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Lithuanian Summary

Sparčiai vystantis dirbtiniam intelektui (DI) ir debesijos kompiuterijai, bankų sektoriuje vyksta reikšmingi technologiniai pokyčiai, kurie leidžia gerinti veiklos efektyvumą, rizikos valdymą ir paslaugų kokybę. Nepaisant šių galimybių, DI ir debesijos sprendimų integracija į pagrindines finansines operacijas vis dar sudėtinga dėl reguliavimo reikalavimų, senųjų sistemų, saugumo rizikų ir specialistų trūkumo. Mokslinėje literatūroje aptariami DI ir debesijos privalumai, tačiau nėra vieningos metodikos jų integracijai bankuose vertinti. Tai sudaro pagrindinę šio tyrimo mokslinę problemą.

Tyrimo objektas – DI ir debesijos inovacijų kokybinis vertinimas pagrindinėse bankų operacijose. Tyrimo tikslas – parengti kokybinius vertinimo kriterijus ir sukurti jų taikymo modelį.

Tyrime taikyta kokybinė metodologija. Duomenys surinkti naudojant struktūruotą klausimyną, kurį užpildė aštuoni ekspertai iš įvairių technologinių ir operacinių bankų sričių. Naudota literatūros analizė, teminė analizė. Tarptautinių bankų analizė papildė ekspertų įžvalgas.

Tyrimo metu nustatyti šeši kriterijai, apibūdinantys DI ir debesijos integracijos efektyvumą: veiklos efektyvumas, mastelio keičiamumas, rizikos ir atitikties valdymas, kibernetinis saugumas, klientų patirtis ir inovacijų geba. Taip pat identifikuotos pagrindinės kliūtys ir sėkmės veiksniai. Remiantis rezultatais, sukurtas kokybinių kriterijų taikymo modelis, suteikiantis bankams struktūruotą priemonę technologiniam brandumui vertinti ir tolimesnei giliųjų technologijų integracijai planuoti.

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INTRODUCTION

Novelty and relevance of the topic. The 21st century has been characterized by an accelerated rate of technological development which has changed the way many businesses operate and accelerated the shift toward a digital environment (Dybek, 2023). For financial institutions such as banks this has required a transformation of their operational structures and technological infrastructure as well as their decision making processes. In spite of the ongoing digitization of their services, core banking activities continue to be plagued by inefficiency due to legacy systems, high operating costs and increasing regulatory pressures. Consequently, banks are increasingly turning to innovative technology solutions to modernize their operations and remain competitive.

Two of the most impactful deep-tech innovations that could potentially optimize core banking operations are artificial intelligence and cloud computing. AI allows for automated decision-making, real time analytics, improved risk management and personalized services (Dybek, 2023). Cloud computing offers scalable, flexible and cost efficient data storage and processing options (Russell & Norvig, 2016). Together, they enable banks to enhance the operational efficiency of their core operations (Vinoth et al., 2022), improve compliance and accelerate innovation (Russell & Norvig, 2016).

Although there are great possibilities for implementing AI and cloud solutions, they are difficult to integrate. Banks experience a variety of obstacles when attempting to implement new technology solutions including stringent regulatory requirements, cybersecurity risks, legacy system incompatibility issues, and specialized personnel shortages. These impediments slow the pace at which banks adopt deep-tech solutions and the extent to which the bank realizes its investment in technology. Although existing literature provides a comprehensive overview of both the benefits and drawbacks of AI and cloud computing, it lacks a singular and specific to banking model that evaluates the integration of AI and cloud solutions to their respective core operations.

The originality of this research is based upon developing qualitative assessment criteria and a formalized model to evaluate the integration and effect of AI and cloud solutions in banking. There is little evidence of academic research combining the technical, organizational and regulatory elements of evaluating AI and cloud integration into one evaluation methodology. Therefore, this thesis aims to fill this knowledge gap by providing a practical and methodically grounded , qualitative model that assists banks to measure their technological maturity and identify the barriers and facilitators of successful deep-tech adoption.

Scientific issue. Although AI and cloud solutions offer significant opportunities for enhancing efficiency, risk management, and service quality, banks lack a systematic and

criteria-based approach to assess the effective integration of AI and cloud solutions. The current methodologies fail to adequately take into account the regulatory, operational and technological specifics of the banking industry. This limits the ability of banks to assess the quality of technology, understand the barriers to implementation, and plan for the adoption of deep-tech. The absence of a structured evaluation model represents the core research issue of this thesis

The object of the research. The application of Artificial Intelligence and Cloud innovations in optimizing core financial operations in the banking sector.

Goal of the research. To develop qualitative criteria for evaluating AI and cloud innovations in core banking operations and to propose a model for applying these criteria effectively

Research Tasks.

1. Analyse theoretical aspects of AI and cloud innovations relevant to core banking operations, identifying their characteristics, advantages, and limitations.
2. Conduct qualitative expert research to clarify the concept of technological quality, identify key implementation challenges, and determine the most relevant qualitative criteria for evaluating AI and cloud integration.
3. Using case study analysis, examine the practical application of the identified qualitative criteria in selected banking sectors.
4. Based on theoretical insights and empirical analysis, propose a model for applying qualitative criteria to evaluate the integration and effectiveness of AI and cloud innovations in core banking operations.

The methods and resources of research. Literature reviews, statistical data analysis, case study analysis, qualitative expert interviews, modeling were used as the research methods. Descriptive-theoretical, systematic, comparative analysis methods were used to study AI and cloud solutions and their relationship to banking methods to examine AI and cloud technologies and their relevance to banking. Generative AI tools such as OpenAI, ChatGPT model 5, were used to systemise and aggregate some of the findings, as well as, investigate ideas, find correct wordings or suggest structures for questions.

Expert opinions are collected using structured interviews or questionnaires. Qualitative data analysis supports selection of countries and banks for case analysis and helps identify institutions demonstrating leading practices in AI and cloud adoption. Some of the exprets

On the basis of the theoretical insights and the results of the empirical research, a conceptual model will be developed to assist banks to evaluate their technological maturity and assess the degree of success of the integration of AI and cloud innovations into core operations.

1. DEEP-TECH INNOVATION IN BANKING: THEORETICAL AND ENTREPRENEURIAL PERSPECTIVES OF ARTIFICIAL INTELLIGENCE AND CLOUD COMPUTING

The 21st Century is characterized by the most rapid technological developments ever seen, as deep tech innovations based on major scientific and engineering breakthroughs are changing many aspects of society, especially in the financial industry. Artificial intelligence and cloud computing will be the two driving forces behind the disruption and progress of banking institutions in terms of their business model and operational architecture, strategic flexibility, and service offerings (Dybek, 2023; Russell & Norvig, 2016).

Artificial intelligence, in general, refers to a type of computer system which is capable of performing tasks that normally require human intelligence. The last decade has seen significant advancements in AI from the use of simple rules-based algorithms to the implementation of more complex self-learning models using techniques like machine learning, deep neural networks, and generative frameworks (Russell & Norvig, 2016; Chowdhary, 2020). For example, in the banking and finance sectors, AI makes possible the real-time detection of fraudulent transactions, personalized customer interaction, the prediction of customer credit-worthiness and the automation of regulatory compliance. For example, recent academic research shows that machine learning models enable financial institutions to enhance credit risk assessment by exploiting complex behavioural patterns and alternative data sources, leading to improved default prediction relative to traditional scorecard based methods (Berg et al., 2020). At the same time, artificial intelligence techniques are increasingly applied in transaction monitoring systems, where large scale payment data are analysed to identify anomalous patterns associated with fraudulent activity, thereby strengthening fraud detection capabilities in modern banking environments.

Cloud computing, however, is the platform upon which all AI applications are built and deployed. Cloud computing allows for the deployment of AI solutions in a flexible, scalable and cost-effective way. Furthermore, cloud computing offers banks the ability to acquire on demand the resources required to run their applications (such as memory, CPU power etc.), integrate their internal and external data sources across multiple platforms, deploy their digital financial services quickly and easily, and remove the operational and technical barriers associated with running IT systems (Zhang, 2022). Cloud computing also supports the large amounts of data required to run AI applications and therefore provides the required computational flexibility for the training of models, the conduct of real-time analysis, and the

operation of AI-as-a-Service (AIaaS) ecosystems to support the various activities of a bank (Zhang, 2022).

Therefore, the combination of AI and cloud computing represents a classic example of a deep-tech path characterized by long periods of development time, high research and development (R&D) intensity and a high degree of scalability potential. With the combined application of these two technologies, banks have the opportunity to go beyond incremental improvements in their current operations and embrace a full-scale transformation of their businesses. A number of key processes including loan processing, know-your-customer (KYC) due diligence and financial forecasting, are being carried out today through cloud-hosted AI models, resulting in lower operational costs, higher levels of analytical sophistication and faster response times (Vinoth et al., 2022).

Despite the potentially transformative benefits of this combined technology stack, there remain a number of challenges facing the banking industry in its adoption. Furthermore, because AI raises important questions about ethics and governance, specifically regarding transparency, fairness and accountability, effective oversight mechanisms and the need for international standards will be essential (Chethan et al., 2024).

This chapter is the first step in analyzing the integration of deep-tech into banking by defining theoretically the AI and cloud computing technologies and identifying the key components of each. The chapter also sets the stage for understanding how banks may utilize the capabilities of deep-tech to develop operational excellence, customer-centricity and sustainable competitive advantage in the digital age.

1.1 Definition and Theoretical Foundations of Machine Learning

Machine Learning was formally defined by Shalev-Shwartz & Ben-David in 2014 as "the field of study whose objective is to give machines the capacity to learn, i.e., improve their performance on a given task through exposure to data." In addition to formal definitions, algorithms are considered to have learned when there is a correlation between the amount of data they receive and improved performance on a particular task. Machine Learning has been described as the intersection of computer science, statistics and optimization theory and focuses on the development of models to identify patterns or relationships from empirical data to support decisions.

Machine Learning does not represent one methodological approach, but rather a range of algorithmic approaches for solving various types of learning problems; supervised, unsupervised and reinforcement learning, which have unique mathematical assumptions and applications (Shalev-Shwartz & Ben-David , 2014).

Types of Machine Learning

Supervised Learning s defined by some labeled examples (a set of input-output pairs), which are then used to train a model to predict an output given an input. This process allows the model to develop a mapping between the inputs and outputs that can be generalized to new, unseen data; the supervised learning paradigm is the most commonly employed paradigm in banking to address many types of problems, including predicting whether a borrower will default on a loan, predicting when a bank's customer will stop doing business with the bank (customer churn modeling), and determining how much risk a lender should take when granting a line of credit (credit scoring) (Shalev-Shwartz & Ben-David, 2014).

Unsupervised Learning is defined by some examples without labels, which are used to find natural groupings of the examples, or to identify interesting patterns in the examples. Examples of unsupervised learning include clustering algorithms and dimensionality reduction techniques. Unsupervised learning has been used in banking to segment customers, to detect unusual activity in account transactions, and to analyze the behavior of their customers (Shalev-Shwartz & Ben-David, 2014, Dybek, 2023).

Reinforcement Learning provides continued interaction with both agents and their environments and has been utilized in a wide variety of applications including but not limited to control, robotics, and autonomous systems. Advances in deep and multi-agent reinforcement learning have allowed for scalable learning in complex and dynamic environments through coordination among multiple agents, and through continuous policy updates in response to delayed and distributed feedback (Hu et al., 2024; Tang et al., 2025). As a result, reinforcement learning has increasing relevance in applications within finance that include dynamic portfolio optimization, real time bidding, and adaptive pricing, which require consideration of strategic interactions, uncertainty, and the constantly changing environment of an evolving marketplace.

Because it can generate patterns and make predictions based on past history by learning from a large body of data, ML is uniquely suitable to banking because of its ability to be self-teaching. Examples of how ML has been used in banking include credit scoring, fraud detection and automated trading (Russell & Norvig, 2016). For example, ML models are able to use non-traditional data for credit worthiness evaluations and also evaluate anomalies in transactional data to alert fraudulent activity. Additionally, some organizations report they have reduced their fraud cases as a result of using AI-based monitoring systems (McKinsey & Company, 2021).

1.2 Definition of Natural Language Processing and Generative Artificial Intelligence

Natural Language Processing (NLP) is a subset of artificial intelligence and involves the ability of a computer to understand, create and communicate through human language in a way that is meaningful to humans. Practically, NLP utilizes a combination of symbolic and

statistical methods to analyze the various forms of language structures (such as syntax, semantics, discourse and pragmatics) to develop an understanding of language (Chowdhary, 2020). Theoretical foundations of NLP exist within the realm of formal linguistics and computational modeling and include the application of tools such as syntactic parsing, semantic role labelling and probabilistic modeling to account for the ambiguity and variability present in human language (Chowdhary, 2020). Over the past few years, machine learning and deep learning have played a significant role in improving the context sensitivity and generalization abilities of NLP for multiple language-related tasks (Khurana et al., 2022). Specifically, neural network-based models, and particularly transformer-based models, have greatly improved results in applications such as machine translation, sentiment analysis and question answering. The rapid advancement in areas such as information extraction, machine translation and grammar checking reflect both increasing scientific interest in NLP and the continued methodological improvements in the field of NLP. These developments enable NLP to support numerous practical functions, such as fully automated conversational systems, as well as real-time compliance monitoring within financial service organizations, thus demonstrating its importance in today's AI systems.

Generative Artificial Intelligence, represent a key area of advancement in artificial intelligence and have the capability to produce complex, coherent and contextually relevant material without human input. LLMs are primarily reliant upon deep learning architectures such as transformers that have allowed for substantial advancements in natural language generation, code synthesis and document summarization (Chowdhary, 2020). Essentially, these systems are founded upon the principles of probabilistic modeling and unsupervised learning; extremely large datasets are utilized to predict the next token in a sequence, thereby enabling the generation of semantically rich synthetic text. Today, generative models are increasingly being employed in critical areas such as financial services where they provide support to tasks including the automation of report creation, prediction of market commentary and simulated risk scenario simulations utilizing synthetic data (Chowdhary, 2020). Due to the scalable nature of LLMs, they enable more personalized interactions between individuals and companies, since content and recommendations may be dynamically adapted to the individual user profile. Thus, while generative AI acts as a generator of content, it also acts as a simulator of human-like interaction and as a stress-tester for digital systems in data-scarce environments. Consequently, the ongoing progression of LLMs affirms their standing as a deep-tech innovation that integrates language comprehension and generative capabilities and is currently in the process of altering traditional workflows in all types of industries.

1.3 Evaluating AI Implementations in the Banking Sector

Evaluating the implementation of Artificial Intelligence in the banking sector requires a structured, evidence-based framework that incorporates both measurable performance outcomes and governance-oriented qualitative criteria. The need for such frameworks is reinforced by findings from global AI governance studies, which highlight that without systematic evaluation, AI adoption risks amplifying biases, undermining transparency, and compromising compliance in highly regulated industries such as banking (Corrêa et al., 2023; Mirishli, 2024).

Table 1 Applications of AI in Banking Functions

Function	AI Application	Benefit
Customer Service	Chatbots, Virtual Assistants	24/7 support, lower costs
Risk Management	Predictive Analytics, Fraud Detection	Real-time alerts, reduced losses
Operations	Robotic Process Automation (RPA)	Improved efficiency
Compliance	NLP for Regulation Analysis	Faster compliance reporting
Investment Advisory	AI-based Portfolio Management Tools	Personalization and insights

Source: Zhang, 2022; Vinoth et al., 2022

Operational Efficiency Gains - Banks can measure the effects of AI on operations through time to complete processes, error rates, and the amount of manual intervention required. According to Mirishli (2024), AI-based solutions like automated contract review platforms can lower analysis times from "thousands of hours" to "seconds," especially for large volumes of legal and compliance work.

Accuracy and Risk Reduction - As well as other areas, predictive models based on AI have demonstrated an improvement in fraud detection, credit scoring, and anti-money laundering (AML) monitoring. Metrics like true positives and false positives, precision, and recall are important for measuring AI's effectiveness in these areas (Mirishli, 2024).

Financial Return on Investment (ROI) - ROI assessments will take into account, changes in cost-to-income ratio, net income margin and incremental revenue generated through AI-driven personalized services. Global market projections show that AI-enabled

intelligent automation will create significant profitability opportunities in banking (Mirishli, 2024).

Regulatory Compliance Performance - egulatory compliance may include the accuracy of transaction monitoring for AML purposes, adherence to PSD2 reporting duties and a reduction in compliance breaches. Measurable benchmarks for compliance for AI-based applications under the EU AI Act are provided through AI's role in meeting high-risk application requirements (Mirishli, 2024).

Fairness and Non-Discrimination - Fairness and equity were identified as two of the most frequent ethical principles in AI-related global policies by Corrêa et al. (2023), as they appear in almost all reviewed policy standards. Equity in lending, pricing and risk assessment in AI-based banking applications must be evaluated to avoid inequitable results.

Transparency/Explainability - The "black box" nature of some AI models provide challenges for both customer confidence and regulatory oversight. High-risk AI applications for finance are mandated to be explainable under the EU AI Act, which demands either interpretable models or explainability tools (Mirishli, 2024).

Responsibility and Governance - Responsibility and governance frameworks should clearly assign responsibility for oversight of AI applications, so that senior management has responsibility for the ethical and compliant use of AI. This is consistent with the accountability principle identified in over 70% of the 200 AI governance documents examined globally (Corrêa et al., 2023).

Compliance with Data Protection and Privacy - Requirements related to GDPR, specifically regarding data minimization and purpose limitation, will directly affect how AI functions in banking. The evaluation should verify whether data treatment and processing procedures follow these principles while continuing to enable model functionality (Mirishli, 2024).

Flexibility and Resilience - Flexibility and resiliency must be assessed for AI-based applications, as they need to be capable of adapting to new market data, mitigating model drift. Best practices in AI governance literature recommend regular monitoring and periodic audit for AI applications (Corrêa et al., 2023).

In conclusion, AI implementations in banking require a balanced approach that combines quantitative metrics, such as operational efficiency gains, prediction accuracy, and financial returns with qualitative safeguards, such as fairness, transparency, accountability, compliance with privacy rules, and flexibility. Literature reviews indicate that focusing solely on the technical performance of AI-based applications without governance considerations could damage trust, compliance with regulations and long-term viability (Mirishli, 2024; Corrêa et al., 2023). Structured evaluation frameworks can help banks ensure that AI-based applications meet both the objectives of operational excellence and ethical integrity, and

thereby obtain a competitive advantage in a dynamic regulatory and technological environment.

Table 2 AI Banking Evaluation Framework: Quantitative vs. Qualitative Criteria

Quantitative Criteria	Examples / Metrics	Qualitative Criteria	Examples / Metrics
Operational Efficiency	Processing time reduction, error rate decrease, automation ratio	Fairness & Non-Discrimination	Bias detection audits, demographic parity tests
Accuracy & Risk Reduction	Precision, recall, true/false positive rates in fraud/credit models	Transparency & Explainability	Explainability audit reports, model interpretability score
ROI	Cost-to-income ratio, net profit margin change	Accountability & Governance	Governance framework review, oversight role mapping
Compliance Performance	Accuracy of AML/PSD2 reporting, compliance breach frequency	Data Protection & Privacy	GDPR compliance audit, data minimization adherence
		Adaptability & Resilience	Model drift detection reports, retraining frequency

Source: Mirishli (2024) and Correa et al. (2023).

1.4 Definition of Cloud

Cloud computing refers to the delivery of shared, configurable computing resources such as networks, servers, storage, applications, and services over the Internet on demand, enabling rapid provisioning with minimal user effort (Buyya et al., 2009; Mell & Grance, 2011). These services are supported by large-scale data centers distributed globally, allowing users to access resources regardless of location, provided they have Internet connectivity (Marinescu, 2017). This model allows organizations to consume IT resources as utilities, reducing the need for investment in physical infrastructure (Buyya et al., 2009).

According to NIST, cloud computing is defined by five essential characteristics: on-demand self-service, broad network access, resource pooling, rapid elasticity, and measured service (Mell & Grance, 2011). Together, these enable scalability, flexibility, and cost efficiency, which drive cloud adoption across public and private sectors (Avram, 2014; Marinescu, 2017).

Cloud services are typically delivered through three models: Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS). SaaS provides fully managed applications over the Internet (Armbrust et al., 2010). PaaS offers development environments without infrastructure management (Avram, 2014). IaaS delivers virtualized computing resources with full user control (Hon & Millard, 2018).

Cloud deployment models include public, private, hybrid, and community clouds, which differ in ownership, access, and management structure (Vinoth et al., 2022; Hon & Millard, 2018).

The global cloud market is dominated by Amazon Web Services, Microsoft Azure, and Google Cloud Platform, with additional major providers including IBM, Oracle, and Alibaba. These vendors continuously expand their service offerings to maintain competitiveness (Gartner, 2022; Synergy Research Group, 2023).

1.5 Characteristics of Cloud Computing in Banking

The adoption of cloud computing in the banking sector is primarily driven by its capacity to deliver on-demand, scalable, and technologically advanced solutions that align with the dynamic requirements of modern financial services. The on-demand self-service model allows banks to provision computing resources such as storage, processing power, and applications without direct human intervention from service providers, thereby accelerating deployment cycles for new services (Mell & Grance, 2011).

Scalability is another defining characteristic, enabling financial institutions to adjust computing capacity in real time to meet fluctuating transaction volumes, seasonal peaks, or unexpected surges in demand. This elasticity supports operational resilience and ensures uninterrupted service availability, which is critical in high-volume banking environments (Marinescu, 2017).

Cloud platforms also facilitate integration with modern technologies such as artificial intelligence, machine learning, and big data analytics. By providing high-performance computing capabilities and extensive data storage, cloud infrastructure enables banks to develop advanced analytics for fraud detection, customer behaviour modelling, and personalised financial products (Cheng et al., 2022).

Furthermore, resource pooling allows banks to share computing infrastructure while maintaining strict segregation of data through virtualisation and encryption, optimising cost efficiency without compromising security (Hon & Millard, 2018a). The pay-as-you-go billing model further enhances financial flexibility, allowing banks to align IT expenditure more closely with operational needs (Avram, 2014).

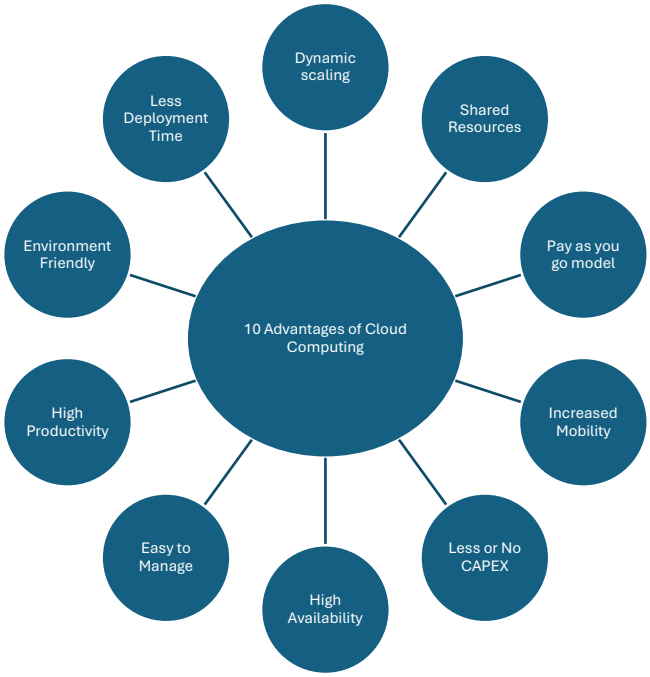
Collectively, these characteristics position cloud computing as a strategic enabler for banks seeking to modernise legacy systems, improve operational agility, and deliver innovative, customer-centric services while maintaining regulatory compliance and security standards.

1.6 Drivers for Cloud Adoption in Banking

The banking industry's rapid migration to cloud computing has been driven by the ability of cloud-based systems to provide flexible, scalable and cutting-edge solutions that can be delivered on an "as needed" basis and are directly responsive to the evolving nature of financial services. Cloud computing's on-demand self-service provides banks the ability to rapidly deploy compute resources (i.e., storage, processing capacity, etc.) and applications without having to interface directly with their service provider, thus dramatically reducing the amount of time it takes to deploy new digital banking services (Mell & Grance, 2011). Additionally, the scalability provided by cloud computing enables institutions to dynamically allocate computing resources based on changing demands from customers or fluctuations in volume due to peak periods of activity, thereby providing continuous availability and operational resilience in high-transaction volume banking environments (Marinescu, 2017).

Cloud-based platforms have the capability to support advanced technologies including AI, machine learning and big data analytics. This is achieved through cloud-based platforms' access to high-performance computing resources and large scale data storage. As a result, banks are able to create sophisticated applications for detecting fraudulent transactions, modeling customer behavior and providing personalized financial products and services (Cheng et al., 2022). Resource pooling and virtualization in cloud computing also contribute to increased efficiency in terms of cost, by utilizing common infrastructure and virtualizing physical hardware, respectively. Virtualization and encryption, therefore, enhance the security of data within cloud computing models, as they enable data to be isolated from other users, both physically and logically (Hon & Millard, 2018a). Finally, the pay-as-you-go pricing model used in cloud computing further increases an institution's financial flexibility, as IT expenditures can now be directly tied to an organization's actual operational needs (Avram, 2014). Together, all of these features make cloud computing a critical component of modern banking, as well as an enabling technology for creating agile operations and innovative customer experiences under a highly regulated environment bringing mltiple benefits for the business (see figure 1)

Figure 1 Advantages of Cloud computing



Source : Vinoth et al., 2022

1.7 Evaluation criteria for cloud computing in the banking sector

The evaluation standards for using cloud computing in the banking industry will be evaluated from a multi-faceted view which assesses both strategic value and operational feasibility of cloud based systems. The first major area of evaluation will be cost and operational efficiency. As Avram (2014) has indicated, although an institution may experience transitional costs due to the time required to integrate and migrate to a new system, once the transition process is completed, institutions have reported long-term cost savings by improving their ability to scale up or down in response to changes in demand, through improvements in automation, and through increased agility.

Risk management and security are additional important areas of evaluation when considering cloud computing, as cloud computing platforms create risks for institutions related to data breaches, unauthorized access, and vendor dependence, and therefore require robust encryption, monitoring, and governance frameworks to protect against those risks (Zhou et al., 2010; Vinoth et al., 2022).

A third important evaluation criterion will be regulatory compliance. For example, in many jurisdictions such as those in the European Union, institutions that utilize cloud computing to outsource critical banking functions must comply with specific audit, data locality, and contractual requirements, and as Hon and Millard (2018) noted, these regulatory

requirements often result in a lack of clarity in terms of supervisory interpretation, which creates uncertainty.

Customer trust and customer adoption of cloud based banking services will also be an important factor in determining whether cloud based banking services are successful, as customer perceptions regarding the reliability, cost effectiveness, and privacy of cloud based banking services will directly impact customer adoption (Asadi et al., 2017).

Finally, the ability to leverage emerging technologies (i.e., artificial intelligence, blockchain, etc.) to improve the strategic case for cloud migration will be an important area of evaluation. These technologies have been identified as being useful in various applications in banking including fraud detection, risk modeling, and personalized financial services (Cheng et al., 2022).

Therefore, it is necessary to consider all of these evaluation criteria when assessing the adoption of cloud computing in the banking industry to ensure that institutions achieve both sustainable competitive advantage and operational security.

1.8 Definition of deep-tech and Integrating AI and cloud as a deep-tech stack in banking

Deep technology, or “deep tech,” denotes a category of innovation grounded in fundamental scientific breakthroughs or substantial engineering advances that are aimed at solving highly complex societal or industrial problems. Such innovations typically require prolonged research and development cycles, significant capital investment, and specialized multidisciplinary expertise before reaching commercial viability (European Institute of Innovation and Technology , 2023). Unlike incremental or purely software-based innovation, deep-techis characterised by high technical risk-often involving unproven scientific principles-while market risk is comparatively lower due to the anticipated transformative value of the solution (European Institute of Innovation and Technology, 2023).

A defining characteristic of deep-techis its capacity to generate defensible intellectual property that is difficult to imitate, positioning it as a critical driver of competitive advantage in emerging markets. Furthermore, deep-techventures rely heavily on strong innovation ecosystems that foster collaboration between academia, industry, investors, and policymakers (Romme et al., 2022). The Eindhoven ecosystem, for example, illustrates how long-term commitment to research infrastructure, public-private partnerships, and talent development can transform a region into a leading deep-techhub despite global competition (Romme et al., 2022).

The technological domains encompassed by deep-techare diverse and include advanced computing, quantum technologies, artificial intelligence, biotechnology, advanced materials, sustainable energy, and blockchain systems (European Institute of Innovation and Technology, 2023). Beyond their technological novelty, these ventures hold strategic significance in addressing grand global challenges such as climate change, sustainable energy transition, healthcare innovation, and industrial transformation. As such, deep-techrepresents not only a technological paradigm but also a socio-economic and strategic innovation model that is inherently tied to ecosystem resilience and sustainability objectives.

1.9 Deep-tech entrepreneurship and strategic relevance to financial services

Deep tech entrepreneurship refers to developing businesses based on novel and complex technological advancements, which in most cases are derived from scientific or engineering breakthroughs made in research institutions, industrial labs, etc. As opposed to traditional tech startup companies, deep tech entrepreneurs must deal with extended R&D periods, large investments, highly skilled personnel and equipment and therefore must be able to successfully navigate intellectual property rights, regulatory frameworks and different ecosystems to connect technological breakthroughs with commercial business models (European Commission, 2023).

In financial services, deep tech has a transformative impact by creating operational efficiencies and new business models. Advanced AI, Quantum Computing, Distributed Ledger Systems, and Privacy-Preserving Computation, etc. can radically change how financial services are delivered by changing how risk modeling, fraud detection, automated compliance, and customer interaction occur (ESRB, 2020). Additionally, they create real-time analytics, automate decisions, increase the level of security in transactions, and allow for the development of new types of financial products and services.

Deep tech provides a barrier to entry and therefore a way to achieve a sustained competitive advantage in the financial services industry due to its defensibility of the created intellectual property (Romasanta et al., 2021). The ability of banks to participate in collaborative innovation ecosystems, where banks, startups, universities and technology companies work together to develop open banking and platform-based service models, will further facilitate their use of deep tech (European Commission, 2023).

However, there are still challenges associated with integration. The long timeframe, high degree of uncertainty and high initial cost required for the adoption of deep tech require patient capital, specialized investment vehicles and long term strategic commitment (European Commission, 2023). Deep tech adoption may also lead to changes in competitive dynamics, regulatory oversight and levels of consumer trust, and thus require flexible governance frameworks (Goldstein et al., 2019).

Ultimately, deep tech entrepreneurship presents the financial services sector with opportunities for improved resilience, innovation leadership and the solution of systemic problems (such as financial inclusion, fraud prevention and digital sovereignty), provided that appropriate ecosystems and supportive policy environments are established to facilitate integration.

1.10 Architectural complementarities between AI and cloud

AI and cloud computing represent a mutual reinforcement of the underlying technological architecture for implementing deep-tech innovations in the banking sector. Specifically, AI's capability for advanced data analysis, prediction models, and automation of tasks relies on scalable and flexible computing resources, which can be efficiently provided via cloud-based infrastructures (Hurson & Wu, 2021). Cloud-based platforms offer elastic computing power, distributed storage and high speed networking, which enable AI models to be developed, deployed and continuously updated at scale, thereby supporting the ongoing learning and adaptation needs within rapidly changing financial environments.

Beyond the simple benefits of operational convenience, the complementary relationship between AI and cloud-based architectures represents a strategic capability. Cloud-based architectures serve as the foundation for integrating AI-based services into both current and future banking systems, thereby facilitating the real-time processing of massive transactional datasets and the rapid identification of anomalies, fraud patterns, and emerging risks. Furthermore, the modular nature of cloud-based native architectures enables the development and deployment of AI based innovations (such as intelligent credit scoring, compliance automation and adaptive customer interaction systems) in an iterative and scalable manner across various banking channels (Legapriyadharshini et al., 2024).

Finally, the architectural synergies between AI and cloud further enhance the defensibility and scalability of deep-tech solutions through the incorporation of sophisticated security, privacy preserving computation, and regulatory compliance into the basic computational framework. The cloud-based deployment of AI-based anomaly detection, encryption and blockchain enabled access control enables the seamless integration of AI-based functionality into financial data processing systems, and therefore ensures that financial data processing occurs securely and with audit trails. From a deep-tech perspective, this layered integration results in an innovation stack where AI, cloud and additional technologies (such as distributed ledgers and quantum resistant cryptography) operate synergistically to produce high-value and resilient financial services.

Strategically, the combined use of AI and cloud accelerates the time-to-market for deep-tech innovations in the banking sector while reducing operational friction and enabling cross-system collaboration among participants in financial ecosystems. Interoperability

standards for cloud-based technologies enable the integration of third party fintech providers, and AI-based analytical capabilities enhance the value of these integrations through the generation of actionable insights and optimized decision-making processes. The AI/cloud-based architectural relationship therefore increases the efficiency and adaptability of banking operations, and also drives the transformation of the banking sector towards open, platform-based, and innovation driven financial ecosystems.

2. GLOBAL MARKET ANALYSIS OF DEEP-TECH ADOPTION IN BANKING THROUGH AI AND CLOUD COMPUTING

In order to determine which countries and banking markets to study regarding deep-tech adoption, the focus needed to be on countries and banking markets that are recognized as among the true leaders in the use of both artificial intelligence and cloud computing. Most people recognize the United States as a leader in technology when discussing the subject. The United States' largest financial institutions, along with the U.S. FinTech ecosystem, are pioneers in using digital transformation to push the boundaries of what can be accomplished through the migration of large-scale workloads to public cloud platforms, and the use of AI in applications such as customer analytics, credit scoring, and fraud detection. Many times U.S. banks, including Capital One, who have committed to using Amazon Web Services for the majority of their operations, are referenced as examples of the transition that many other banks will go through as they transition from traditional banking systems to systems that utilize cloud computing and AI (Cheng et al., 2022).

It would be misleading to conclude that the United States has an absolute monopoly on being the leader in the area of deep-tech. China has become increasingly competitive in terms of deep-tech capabilities. With national strategies such as "Internet Plus," Chinese banks have made significant investments in cloud based infrastructure, and AI enabled systems (Wang et al., 2016). These investments have resulted in improvements in the operational efficiency of the banks, as well as enhancements in how the banks handle data; however, there are significantly increased risks associated with the operational aspects of the rapid deployment of such technologies (Cheng et al., 2022). The European Union represents a completely different view point in comparison to the U.S. and China. Banking organizations throughout the EU are slowly transitioning to cloud based systems; however, the rate at which they are able to do so is influenced by a number of factors beyond the influence of the availability of the technology itself. These include strict regulatory frameworks, cultural conservatism, and continued concerns regarding data privacy (Hon & Millard, 2018).

The regions described above represent a variety of paths to achieve deep-tech transformation in banking. The U.S. may be viewed as the innovator; however, the development of deep-tech capabilities in Asia and Europe are just as extensive, and present their own unique combinations of opportunities and challenges. Therefore, when evaluating countries and banking organizations to compare for purposes of research, it is necessary to assess the size of the banking sector in each country. This will provide a basis for comparing the systemic importance of banking in different economies, and ensure that all subsequent comparisons are conducted on a consistent basis.

Table 3 Bank assets as a percentage of GDP across selected countries

Country Name	Country Code	2020 [YR2020]	2021 [YR2021]	Latest
Hong Kong SAR, China	HKG	266.6976	268.8174	268.8174
Macao SAR, China	MAC	283.9117	241.5155	241.5155
China	CHN	218.7431	214.2299	214.2299
Qatar	QAT	235.3550	208.0468	208.0468
Korea, Rep.	KOR	173.3978	181.6619	181.6619
Denmark	DNK	174.8332	169.8754	169.8754
Japan	JPN	170.4161	169.6211	169.6211
Singapore	SGP	168.9756	168.9756	168.9756
Cambodia	KHM	142.8682	166.3253	166.3253
New Zealand	NZL	159.3903	154.4883	154.4883
Malaysia	MYS	158.9077	153.0208	153.0208
Thailand	THA	144.5433	152.0180	152.0180
Australia	AUS	163.7002	148.1807	148.1807
Sweden	SWE	149.5602	145.8413	145.8413
San Marino	SMR	142.3727	-	142.3727
Vietnam	VNM	162.7559	136.1844	136.1844
United Kingdom	GBR	143.2779	136.0174	136.0174
Norway	NOR	155.9760	133.7639	133.7639
France	FRA	137.2652	131.0699	131.0699
United Arab Emirates	ARE	130.6930	-	130.6930

Source: World Bank (2025).

The size of banking sectors can be compared to GDP among many countries and shows large differences among countries. European banking systems like those found in Switzerland and Luxembourg have bank asset to GDP ratios that exceed many hundreds of percent. Thus, they qualify as international banking centers (Wierzbowska, 2025). The U.S., in comparison to other developed financial structures, has low bank asset to GDP ratios at approximately 70-80% showing a relatively diversified financial system where capital markets play a significant role. In Asia, Hong Kong and Singapore show bank asset to GDP ratios far in excess of 200%. China, however, is in the midst of rapid growth and faces challenges of lower transparency and a highly regulated environment, which creates uncertainty when comparing financial systems across countries (Corbet et al., 2023).

In Africa and South America, there is a stark difference between the bank asset to GDP ratio and the size of their banking systems to their overall GDP. Their banking systems are smaller in proportion to GDP, but they are in the process of developing their banking systems and expanding the use of technology to penetrate more areas of society. The disparity in size is similar to studies that have found that the larger the size of the banking sector, the more stable the financial system will be and the more likely it is to adopt new technologies (Ndou & Gumata, 2024).

Given the disparities noted above, the focus of this study will be narrowed to examine the major economies of the world that have been identified as having the most open data regarding their banking systems. These economies include the major economies of North

America, Western Europe and the Nordic regions. These regions were chosen because of their systemic weight in the world economy and the availability of data to support the examination of technological innovation within the banking industry. Additionally, given the recent focus on innovation in Europe, specifically regarding artificial intelligence and cloud computing, and the subsequent creation of the European Innovation Council to create and finance innovation throughout the EU, the choice of the focus on the major economies of Europe seems reasonable (European Commission, 2021; European Commission, 2022).

To further narrow the focus of the research, the largest banks in the United States, major European economies and the Nordic regions were identified based on total assets. The focus on these banks is important because they are considered to be systemically relevant due to their size and potential to influence financial stability. They also have sufficient size and resources to invest in artificial intelligence and cloud computing to support their business model. To compare the level of investment in artificial intelligence and cloud computing in the largest banks in each of the focus regions, three graphs are provided. The first graph compares the largest U.S. banks based on their assets. The second graph compares the largest European banks based on their assets. The third graph provides an overview of the major financial institutions located in the Nordic region. The purpose of providing these three graphs is to serve as a starting point for evaluating how the adoption of artificial intelligence and cloud computing is changing the way that banks conduct their operations in each of the regions.

One bank was selected from each of the focus regions. JPMorgan Chase was selected as the representative bank for the U.S. due to its size and early use of artificial intelligence. HSBC was selected as the representative bank for Europe as it is one of the largest global banks that is using cloud computing to enhance its ability to compete in the global marketplace. Danske Bank was selected as the representative bank for the Nordic region as it has a long history of investing in digital banking and the adoption of new technologies. The combination of the three banks provides a comprehensive look at how artificial intelligence and cloud computing are being used in the banking industry in each of the focus regions.

Table 4 Selected Banks by Total Assets

Bank Name	**Region**	**Total Assets (2024)**	**Characteristics**
JPMorgan Chase	United States	$4.0 trillion (USD)	Largest U.S. bank by assets. Pioneer in AI-driven risk management
HSBC Holdings	Europe	$3.0 trillion (USD)	Global footprint with strong emphasis on digital banking and

			cross-border cloud integration.
Danske Bank	Nordics	DKK 3,739 billion (~€497 bn)	Leader in Nordic digital banking Advanced online services

Source: *JPMorgan Chase & Co. (2024), HSBC Holdings plc (2024), and Danske Bank (2024) annual reports*

The selected banks were evaluated according to their adoption of Artificial Intelligence and Cloud Computing, as per the analytical criteria developed in this study for evaluating deep-technology adoption in the financial sector. The evaluation model for determining if the banks have adopted deep-technologies like Artificial Intelligence and Cloud Computing has been developed around four major dimensions. The combination of dimensions combines established strategic concepts with recent literature on the technological maturity, ecosystem interaction and sustainability of a bank.

The first dimension is innovation and value creation; it was built upon the value innovation loop (Kim & Mauborgne 1999, 2005). They outlined four guiding questions regarding what factors should be lowered to below the industry standard, increased to above the standard, what established practices should be removed and what new elements should be developed. In the banking context, this concept may be applied to determine how the adoption of AI and Cloud is changing value creation, delivery and capture. An example would be how banks are creating new types of personal service utilizing AI and Cloud technologies, removing inefficient practices, or creating new competitive benchmarks.

The second dimension is technological depth and maturity; this dimension assesses if the banks are simply using AI and Cloud as incremental improvements, as efficiency tools, or as outsourced services, or if they are integrating them into long-term technology and innovation strategies. Examples of relevant indicators include the scalability of cloud platforms, the integration of AI applications with cloud platforms, the use of technology readiness levels, and the compliance with standards related to governance and security. Studies by Haefner et al. (2023) and Lins et al.(2021) demonstrate the importance of these indicators in order to ensure that technology deployment in finance is reliable, scalable, and future oriented.

The third dimension is knowledge intensity and ecosystem interaction; deep-tech adoption cannot be solely defined by acquiring technologies, rather it depends on developing and protecting knowledge assets. According to Romme et al. (2023), the role of intellectual property and venture-building structures in deep-tech contexts is highlighted, while studies by Capatina et al. (2024) and Dionisio et al. (2023) illustrate that cooperating with universities, start-ups and fintech companies improves absorptive capacity and accelerates technology transfer. For banks, this means assessing if they are investing in their own R&D, developing

their own proprietary AI solutions, and establishing partnerships that support their competitive positioning.

The fourth dimension is impact and sustainability; deep-tech in financial services does not merely relate to efficiency but also to long-term social and environmental alignment. Aqmala et al.(2025) pointed out how AI contributes to ESG scoring and sustainable finance. From a practical standpoint, this dimension evaluates if the adoption of AI and Cloud in banks improves traditionally accepted efficiency metrics such as Return On Assets (ROA) or Cost-To-Income Ratios while also supporting sustainability through green cloud strategies and ESG integration.

Collectively, these four dimensions develop a compact but comprehensive model for identifying whether the application of AI and Cloud in banking represent simple digitalization or a true deep-tech transformation.

Table 5 Dimensions for Analyzing Deep-Tech Adoption in Banking

Dimension	Analytical Focus	Application
Innovation & Value Creation	Reduced factors below industry standard Raised factors above standard Practices eliminated New elements created	Assess how AI & cloud reshape value creation and delivery
Technological Depth & Maturity	Cloud scalability AI integration Technology Readiness Levels governance, security	Judge if adoption is incremental or deep-tech transformation
Knowledge & Ecosystem	IP strategy R&D intensity, Fintech/startup/university partnerships	Evaluate if banks create/own deep-tech knowledge and leverage ecosystems
Impact & Sustainability	Efficiency, ESG integration, AI for green finance, Sustainable cloud	Test long-term competitiveness and alignment with ESG goals

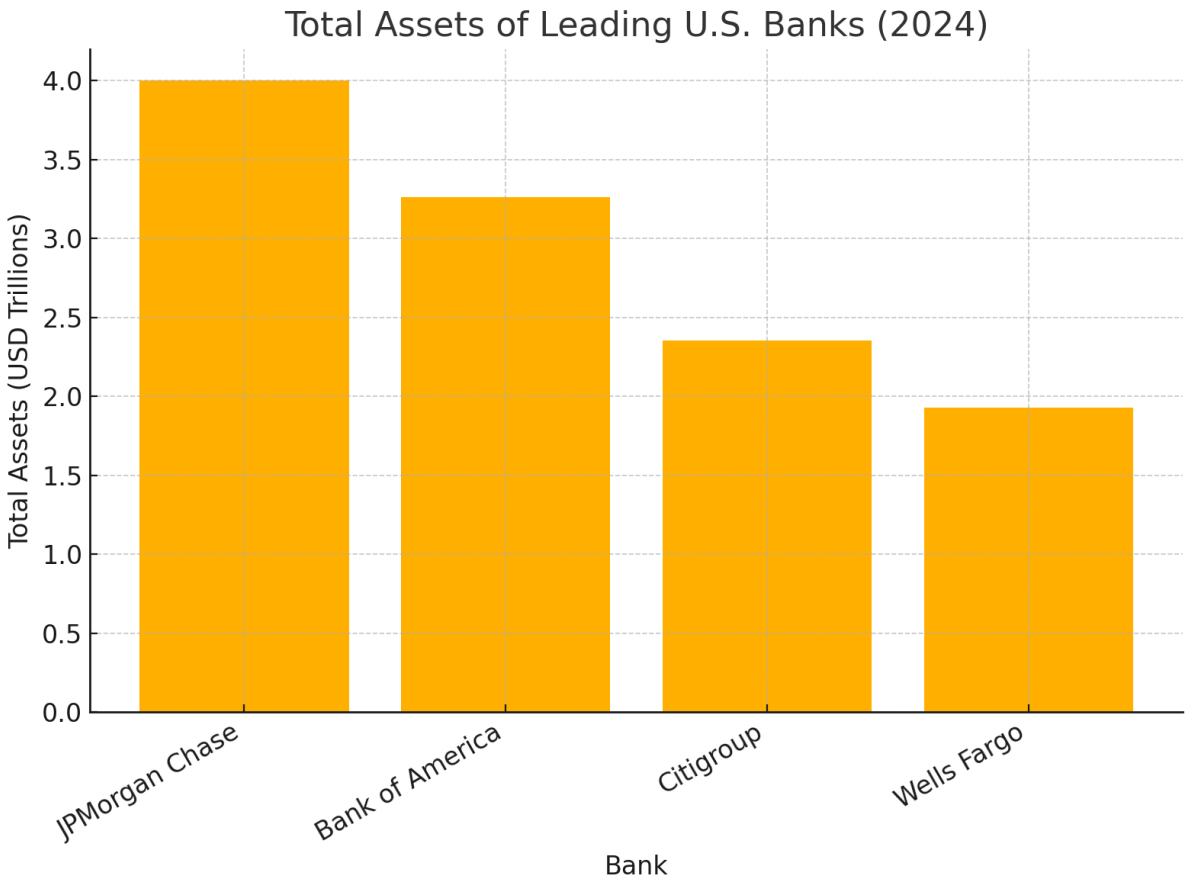
Source: compiled by author

2.1 Artificial Intelligence and Cloud Computing Integration Analysis: JPMorgan Chase Case

JPMorgan Chase & Co. is the biggest financial services firm in the US, possessing nearly $4 trillion in assets that place it among the most systemically critical banks globally (JPMorgan Chase, 2024). JPMorgan Chase is not only the largest bank compared to competitors including Bank of America, Citigroup and Wells Fargo by virtue of size and investment in technology but also the leading bank in terms of technology investment. In addition, the overall U.S. banking industry is characterized by an advanced digital architecture

and is among the leaders in global cloud adoption based on the U.S.-based hyperscalers (Amazon and Microsoft) that dominate this space (IDC, 2023; Synergy Research Group, 2023), which further supports JPMorgan's relevance in studying the deep-tech adoption in banking.

Figure 2 Comparative Total Assets of Leading U.S. Banks, 2024



Source: *JPMorgan Chase & Co., 2024; Bank of America, 2024; Citigroup, 2024; Wells Fargo, 2024).*

Since it's inception JPMorgan Chase has focused on investing in artificial intelligence and cloud computing; two of the most widely recognized areas of innovation in finance and banking that are driving digital transformation (Douglas & Christian, 2024). In an effort to support the growth and development of its business, JPMorgan Chase is spending over 12 billion USD each year on technology including applications of machine learning, digital infrastructure and cloud based solutions (JPMorgan Chase, 2024). The Applied AI and Machine Learning Division at JPMorgan Chase is responsible for developing the various tools used by the company for the purpose of credit risk modeling, fraud detection, natural language processing and trading optimization (JPMorgan Chase, n.d.-a), thus applying AI across both front office and back office operations.

Table 6 JPMorgan Chase & Co Technology investments 2021-2024

Year	Technology Investment (USD Billion)	AI & Cloud Focus
2021	11	Early AI use in fraud detection and customer analytics; hybrid cloud expansion
2022	12	Applied AI group formalized; AI in risk management; cloud migration acceleration
2023	13	Hybrid cloud adoption with AWS & Azure; AI in risk modeling, NLP, trading optimization
2024	12	Enterprise-wide AI integration; generative AI tools in compliance, trading, ops; cloud for resilience

Source. JPMorgan Chase & Co (2024), JPMorgan Chase & Co (2023), JPMorgan Chase & Co (2022), JPMorgan Chase & Co (2021)

The convergence of cloud and artificial intelligence has enabled JP Morgan to achieve both scalable performance, and real-time analytical capabilities that are considered key factors to enable large-scale automation (Douglas & Christian, 2024). This combination is further supported at the practical level by JP Morgan's hybrid cloud partnership agreements with Amazon Web Services and Microsoft Azure, which enable JP Morgan to achieve greater resiliency, better compliance and greater control over its data governance (Gartner, 2022; JPMorgan Chase, 2024). JP Morgan's large size relative to other banks creates a cost barrier for smaller banks to replicate this technology adoption, thus creating a competitive advantage for JP Morgan relative to their smaller competitor banks. In addition to being a leading U.S. bank using artificial intelligence and cloud technology together, JP Morgan represents a model of the application of deep tech across all global banking. Therefore, the next chapter will include additional information about how JP Morgan uses artificial intelligence and cloud technology, after which this paper will use the dimensions for analyzing deep-tech adoption in banking listed in Table 5 to analyze the bank.

2.2 JPMorgan Chase's Implementation of Artificial Intelligence

Over the last 4 years, JPMorgan Chase's implementation of AI has evolved steadily; at each stage, the bank has been influenced by both broader industry trends, as well as its own strategic objectives.

While, in 2021, the Bank recognized AI as being a key enabler in fraud detection, credit scoring and early risk analytics, much of the technology investments made during the course of the year focused on enhancing the banks' digital infrastructure and providing the underlying framework for future large scale cloud integration. The Bank also applied machine learning tools to support the monitoring of transactions and the analysis of customers (JPMorgan Chase, 2021).

In 2022, AI was implemented throughout the organization as part of the Bank's Applied AI and Machine Learning Group. As an organizational entity, the Group is charged with the responsibility of implementing enterprise grade AI solutions across the organizations' trading, compliance, and customer service business lines. One area in which AI is now used more extensively within the organization, is through the application of natural language processing, to increase the efficiency of the organization in managing documents internally, and to provide improved customer services using AI driven chatbots. The use of AI in these areas is consistent with a broader trend in the banking sector, as many banks have begun to implement AI enabled chatbots and mobile apps, as they look to use these types of applications to personalize their products and services, and to engage with their customers (Kaur et al., 2020).

In 2023, the Bank's annual report indicated that AI will be increasingly used in trading optimization and portfolio management, and the Bank has already taken steps to enable the use of AI in these areas. Specifically, AI systems are now integral to the Bank's algorithmic trading models, and are capable of analyzing financial news and sentiment in real-time. Additionally, the Bank continues to apply natural language processing in new areas, such as compliance and legal functions, following the successful application of the COiN platform, which automated the review of complex contracts (JPMorgan Chase, 2023). This is consistent with a broader recognition in academic research that fraud detection and compliance are two of the most impactful uses of AI in banking, because of their reliance on behavioral data and predictive analytics (Kaur et al., 2020).

Finally, the Bank's 2024 Annual Report marks a turning point in the Bank's AI strategy, with the first deployment of generative AI models, across compliance, fraud detection and internal operations. These models were also able to automate many tasks, and assist employees, who can use them to support their productivity. Generative AI models were also represented as a superior way to process unstructured data and to perform dynamic tasks, when compared to traditional machine learning approaches. As a result, AI is no longer viewed solely as a means to support current activities, but rather as a driver of long term strategic transformation, and is seen as fully aligned with the Bank's digital strategy (JPMorgan Chase, 2024). Researchers suggest that the Bank's widespread adoption of AI represents a broader "Banking 4.0" paradigm, in which banking institutions evolve from branch based to digital first business models, which utilize predictive and adaptive technologies (Kaur et al., 2020).

Table 7 JPMorgan Chase AI Initiatives 2021-2024

Year	Key AI Initiatives
2021	AI in fraud detection, credit scoring, and early risk analytics; machine learning for transaction monitoring and customer analytics
2022	Formalization of Applied AI & Machine Learning group; expansion of natural language processing for document handling and chatbots
2023	Deeper integration of AI in trading optimization and portfolio management; COiN platform for legal document review and compliance
2024	Deployment of generative AI in compliance, fraud detection, and internal productivity; AI framed as a strategic driver in digital agenda

Source. JPMorgan Chase & Co (2024), JPMorgan Chase & Co (2023), JPMorgan Chase & Co (2022), JPMorgan Chase & Co (2021)

In conjunction with each other, the advancements seen during the period of 2021 through 2024 illustrate JPMorgan's transformation of incrementally implementing AI in fraud and risk analytics into an organization-wide strategy centered around generative AI. The transformations illustrate the increasingly mature application of AI within JPMorgan as well as the increasing trend of aligning with broader industry trends; the merging of AI and cloud computing is fundamentally changing the way companies create value for their customers and the way companies can be resilient operationally (Douglas & Christian, 2024). Simultaneously, the increasing dependency upon generative AI raises the need for governance, algorithmic bias, and regulatory oversight, areas of concern that academics indicate will define the next wave of financial innovation (Maple et al., 2023). As such, it has been noted by Kaur et al. (2020) that there is a necessity for AI implementation to find a balance between automation and user trust because there remains a group of users who value interacting directly with a human when utilizing a financial service..

2.3 JPMorgan Chase's Implementation of Cloud Computing

The increasing use of cloud computing has been one of the key elements of JPMorgan Chase's technology development and strategy and supports the principles of scalability, efficiency and resilience in the increasingly digitalized banking space. Between 2021 and 2024, the bank created a hybrid cloud model to combine public and private cloud services to meet both the needs for modernization and to comply with regulatory requirements.

In 2021, cloud was seen as a strategic enabler to improve the bank's digital infrastructure and cyber security and to begin migrating workloads to allow greater flexibility and resilience in its operations. However, according to Vinoth et al. (2022), the major reasons why banks are adopting cloud technology include lower costs for IT and disaster recovery and business continuity.

As stated above, between 2022 and 2024 JPMorgan further developed its partnership with Amazon Web Services and Microsoft Azure to create a hybrid architecture that would enhance data management and enable real time analytics for regulatory compliance and decision making (JPMorgan Chase, 2022). This represents the dual role of cloud technology as both an efficiency tool and a base upon which to develop new technologies such as artificial intelligence (Cheng et al., 2022).

By 2023, many of the critical systems at JPMorgan including trading systems, risk models and digital banking were being migrated to hybrid cloud environments (JPMorgan Chase, 2023). Although cloud technology enables improvements in task scheduling, scalability and auditability for managing risk (Zhang, 2022), there are also security and regulatory risks associated with using multi-tenant cloud solutions and relying on third parties to provide these services (Vinoth et al., 2022).

Consistent with the need to address both operational and regulatory risks, JPMorgan also recognized the importance of maintaining robust cyber security and ensuring regulatory alignment as parallel priorities, consistent with the findings of Hon and Millard (2018).

By 2024, JPMorgan had successfully integrated its hybrid cloud solution across all of its global operations allowing for the deployment of generative AI, real-time transaction monitoring and global digital banking services (JPMorgan Chase, 2024). The combination of cloud and AI is now considered to be the industrial backbone of modern finance (Douglas & Christian, 2024).

For JPMorgan, the progression from 2021 through 2024 demonstrates the evolution of cloud technology from a modernization tool to a deep tech enabler of its innovation strategy. The progression during this time period illustrates how JPMorgan transitioned from cautious investments in infrastructure to the complete hybrid integration of cloud technology to support advanced analytics and AI driven services, while balancing the benefits of efficiency and innovation with the risks of external dependency and regulatory risk (Avram, 2014; Vinoth et al., 2022).

Table 8 JPMorgan Chase Cloud Computing Initiatives 2021-2024

Year	Key Cloud Initiatives
2021	Began framing cloud adoption as a foundation for modernization. Focus on digital infrastructure, cybersecurity, and gradual migration of workloads to cloud.
2022	Expanded partnerships with AWS and Microsoft Azure to implement hybrid cloud. Emphasis on regulatory compliance, real-time analytics, and improved data management.
2023	Migration of mission-critical workloads into hybrid environments. Integration of cloud into trading, risk modelling, and digital banking. Strong focus on cybersecurity and resilience.

2024	Significant progress embedding hybrid cloud globally. Cloud platforms supported generative AI, real-time transaction monitoring, and cross-border banking. Positioned hybrid cloud as essential for scalability and flexibility.

Source. JPMorgan Chase & Co (2024), JPMorgan Chase & Co (2023), JPMorgan Chase & Co (2022), JPMorgan Chase & Co (2021)

2.4 Analysis of JPMorgan Chase's Integration of Artificial Intelligence and Cloud Computing Using Analytical Criteria Dimensions

JPMorgan Chase's incorporation of AI and Cloud Computing is an example of how JPMorgan is attempting to use technology to enhance its core operational capabilities for financial services; however, whether or not the investments are truly examples of deep-tech will depend upon how well they align with the three key dimensions of value innovation, customer orientation, and technological maturity. This section will use the analytical framework that was previously identified in the study to analyze JPMorgan's strategy for both the benefits and limitations of its approach.

Innovation & Value Creation

- Increasing industry factors: JPMorgan's investment in technology is greater than that of its competitors; in fact, the bank spends over $12 Billion per year on the development of AI, Cloud and Digital Infrastructure (JPMorgan Chase, 2024).
- Lowering industry factors: JPMorgan has reduced its dependence upon costly legacy IT and Physical Infrastructure by gradually moving workloads to Hybrid Cloud (JPMorgan Chase, 2022).
- Eliminating obsolete practices: JPMorgan replaced the antiquated practice of siloed data management with scalable architectures that provide real-time analytics and regulatory reporting capabilities (JPMorgan Chase, 2023).
- Creating New Practices: JPMorgan has developed Generative AI Initiatives in Compliance, Trading Optimization, and Personalized Services creating new banking practices outside of the boundaries of traditional banking (JPMorgan Chase, n.d.-a).

Conclusion: JPMorgan has been able to reshape the way it creates value through its use of AI and Cloud as described in Kim and Mauborgne's (1999, 2005) Value Innovation Loop by increasing its technological standards while eliminating obsolete technology and systems. That being said, due to the banks reliance on third party vendors for its use of AI and

Cloud there are strategic risks involved which limit its ability to operate autonomously (Avram, 2014).

Technological Depth & Maturity

- Scalability through the Cloud : In addition to expanding their hybrid-cloud platform by adding AWS and Azure, JPMorgan migrated significant parts of its business (trading & risk) to the Cloud for scalability.
- Seamless Integration of AI: The Cloud platforms allowed seamless integration of AI within all areas of Compliance, Fraud Detection, Productivity, and Customer-Facing Services.
- Technology Readiness Levels: At an Enterprise-Wide level is a technology-readiness indicator; however, due to dependence upon external providers for several Critical Systems, the company has not demonstrated complete internal ownership of these systems.
- Governance and Security: The emphasis placed on layered cybersecurity & compliance are indicators that JPMorgan recognizes the vulnerabilities in these areas; however, Multi-Tenancy and Data Localization Risks continue to exist.

Conclusion: JPMorgan demonstrates maturity that exceeds incremental digitalization. It is aligning with deep-tech transformation through scalable cloud and embedded AI. Long-term resilience depends on transparent governance and reducing dependency on external provider (Hon & Millard, 2018; Mancuso et al., 2025).

Knowledge & Ecosystem

- Research & Development (R&D) investment: Although JPMorgan invests heavily into technology, it spends mostly for applied technology deployments, rather than to create new and fundamental R&D breakthroughs.
- Intellectual Property (IP) Strategy: As opposed to using patented inventions in AI or cloud, JPMorgan's innovations rely on partnerships to develop its innovative products and services through an ecosystem of other organizations.
- Partnerships: Through strategic alliances with AWS, Microsoft, fintech companies, and academic institutions; JPMorgan accelerates the implementation of its new technologies but also dilutes its ownership of knowledge and therefore potentially its ability to be independent for a long period of time.

Conclusion: JPMorgan uses an ecosystem well to implement its new technologies, however it has very little control over the proprietary deep-tech knowledge that creates these new technologies, creating long term questions about how dependent the company will remain on others for this knowledge. This demonstrates characteristics of the "Hybrid Deep Tech" model where knowledge is developed and/or resides both inside and outside the organization (European Commission, 2022).

Impact & Sustainability

- Efficiency: JPMorgan has achieved cost reductions through improved efficiency via AI automation in fraud prevention, compliance and legal review, which have enhanced their cost to income ratios.
- ESG integration: JPMorgan have stated that they will integrate ESG into their lending and investment activities, there appears to be little development as yet of integrating AI for the purpose of ESG assessment.
- Sustainable cloud: it is true that cloud computing can be used to improve the energy efficiency of data centres. However, whilst cloud computing reduces the need for expensive hardware on-site, there are ongoing concerns regarding the potential negative impact on the environment caused by the high level of power required by large scale AI applications.

Conclusion: JPMorgan are achieving efficiencies from the use of AI and cloud services, improving their competitive advantage. However, their use of ESG appears to be limited at present, and therefore so too does the environmental sustainability of their use of large-scale deep-tech. (Aqmala et al., 2025; Vinoth et al., 2022).

2.5 Artificial Intelligence and Cloud Computing Integration Analysis: HSBC Case

HSBC Holdings represents one of the largest and most interconnected financial institutions in Europe, with assets totaling in excess of 2.6 trillion EUR in 2024, and is therefore ranked as one of the most systemically important banks across the globe (HSBC, 2024). In contrast, while JPMorgan Chase has a significant footprint in the U.S., HSBC's operational reach encompasses 60+ countries, positioning HSBC as an internationally connected bank.

This global connectivity demands technologies capable of supporting both cross border transactions, numerous and complex regulatory requirements and varied customer needs.

While HSBC is larger than many of its European counterparts (BNP Paribas, Crédit Agricole, Deutsche Bank), HSBC differs from them in its strategic focus on technology and cloud-based partners to effectuate its digital transformation strategy. Like JPMorgan Chase, the size of HSBC creates it as a relevant example to study the adoption of deep-tech in banking and how this impacts both the regulatory and cultural environment of the European Union.

The strategic use of both Artificial Intelligence and cloud computing, as demonstrated through its multi-year commitment to developing digital infrastructure using AI-driven compliance systems, hybrid cloud solutions and others demonstrate a long-term commitment by the bank to enhance the efficiency of its operations, however, more importantly, to create an element of resiliency in a rapidly evolving and increasingly regulated financial services landscape where customer expectations continue to evolve at a rapid pace (Cheng et al., 2022; Hon & Millard, 2018).

Table 9 Comparative Total Assets of Leading European Banks

Bank	Total Assets (EUR trillions)	Source
HSBC (UK)	2.64	HSBC (2024)
BNP Paribas (France)	2.59	BNP Paribas (2024)
Crédit Agricole (France)	2.48	Crédit Agricole (2024)
Deutsche Bank (Germany)	1.34	Deutsche Bank (2024)

Source: HSBC (2024), BNP Paribas, (2024), Crédit Agricole (2024), Deutsche Bank (2024)

HSBC's way of using and adopting deep technology is different from other US based financial institutions. Other US based financial institutions can take advantage of their close relationship to the cloud hyperscalers and they have more flexibility in the regulations than their European counterparties. On a contrary, European financial institutions have to work under a more restrictive legal frameworks and are bound by strict privacy laws that dictate how quickly a bank can adopt new technologies. As a result, for HSBC, it has been a matter of striking a balance between being innovative and complying with regulation, which resulted in a incremental approach to integrating AI into fraud detection, AML/KYC procedures, and personalized customer experiences and to advance hybrid cloud solutions in conjunction with large scale cloud providers like Google Cloud and Microsoft Azure (HSBC, 2024).

Because of these factors, HSBC provides a particularly relevant example for studying how European banking organizations develop strategies to manage both the opportunities and challenges of adopting deep technology. The next several paragraphs will evaluate HSBC's use of artificial intelligence and cloud computing and analyze the bank's integration strategy through the lens of the analytical dimensions of the prior section of this research.

Table 10 HSBC Technology and AI/Cloud Investments 2021-2024

Year	Technology Investment (USD Billion)	AI & Cloud Focus
2021	Approx. 5.8	AI in AML/KYC, early cloud migration pilots
2022	Approx. 6.0	Expanded AI in fraud detection and compliance Cloud partnerships
2023	Approx. 6.3	Hybrid cloud integration with Google Cloud and AWS AI chatbots and credit risk tools
2024	Approx. 6.5	Enterprise-wide AI deployment incl. generative AI Hybrid cloud scaling global operations

Source: HSBC (2021), HSBC (2022), HSBC (2023), HSBC (2024),

2.6 HSBC's Implementation of Artificial Intelligence

From 2021-2024, HSBC further developed their usage of AI, with an increasing focus on compliance, fraud prevention and customer interaction. The progression of their AI development mirrors both the opportunity and limitation of developing new technologies in a heavily regulated European environment, where technological innovation must be managed alongside the need for compliance with data privacy regulation and the minimization of systemic risk.

In 2021, HSBC identified AI as a strategic enabler in the fight against financial crime and in complying with regulatory requirements. HSBC utilized AI to enhance the effectiveness of their Anti-Money Laundering (AML) and Know Your Customer (KYC) systems by using AI to identify unusual trends and patterns within high volume transactions (HSBC, 2021). In 2021, AI was primarily viewed as an operational requirement for HSBC rather than as a means to drive customer facing innovations.

In 2022, HSBC used AI to develop systems for detecting fraudulent transactions and monitoring transactions in real-time, and for implementing early-stage customer personalization through their digital banking channels. HSBC's annual reporting demonstrated how AI driven analytics enhanced both their compliance functions and digital banking services (HSBC, 2022), which supports what academic research has identified as one of the primary

uses of AI in banking; i.e., reducing systemic risk while enhancing the efficiency of service delivery (Cheng et al., 2022).

By 2023, HSBC stated that AI had been integrated at a higher level into their front office services. They implemented chatbots and virtual assistants across their mobile and online services, providing customers with personalized financial information and enhancing their customer experience. Additionally, AI supported credit risk assessments and portfolio monitoring, demonstrating that AI technology was being integrated into strategic decision making processes beyond compliance (HSBC, 2023). The increased integration of AI technology into customer facing services by HSBC reflects an emerging industry-wide trend toward utilizing AI technology as a key component of digital first business models in the banking sector (Douglas & Christian, 2024).

As of 2024, HSBC began integrating generative AI applications into their internal operations, including document management and supporting employee productivity. HSBC's 2024 annual report also described the continued expansion of AI technology in retail banking and corporate advisory services, further solidifying AI technology as a central element of their global digital strategy (HSBC, 2024). Although there are still many unresolved questions regarding the implementation of AI in financial institutions, researchers have noted the potential risks of algorithmic bias in AI decision-making, and the need for greater transparency in AI decision making processes as necessary elements for establishing public trust in the use of AI in financial services (Maple et al., 2023).

Table 11 HSBC AI Initiatives (2021-2024)

Year	Key AI Initiatives
2021	AI-enhanced AML and KYC systems; AI for large-scale transaction monitoring
2022	Expanded AI in fraud detection and compliance; early-stage customer personalization in digital banking
2023	Deployment of chatbots and virtual assistants; AI in credit risk and portfolio monitoring
2024	Generative AI in internal operations and compliance; AI-driven personalization in retail and corporate banking

Source: HSBC (2021), HSBC (2022), HSBC (2023), HSBC (2024)

Collectively, HSBC's path shows an incremental transition from using AI as a compliance-based tool in 2021 to being an enterprise-wide enabler of digital transformation by 2024. While compared to JPMorgan Chase, HSBC's use of AI has been much more measured and guided by regulatory requirements than its U.S.-based competitor; nonetheless, HSBC also exemplifies the deep-tech model that seeks to embed systematic, scientifically driven innovations in banking processes. The development illustrated here reflects how European banks balance governance considerations with innovation opportunities, and further

illustrate the trade-offs between potential efficiency enhancements and the need for transparency and accountability in the introduction of deep tech.

2.7 HSBC's Implementation of Cloud Computing.

HSBC has placed cloud computing at the heart of its long term digital transformation, which it views as necessary to achieve operational efficiency, resilience, and innovation. In terms of the bank's use of cloud between 2021-2024, HSBC has gradually implemented its hybrid cloud model, as well as the regulatory demands of operationally conducting across multiple countries and jurisdictions.

The primary way HSBC viewed cloud adoption in 2021, was through its efforts to modernize and improve efficiencies in how it does things, in addition to mentioning investments made by the bank in digital infrastructure, cybersecurity and the progressive transition of selected workload to the cloud, HSBC noted it operated in a highly regulated environment (HSBC, 2021), and therefore did not have the ability to rapidly or dramatically change its core, mission-critical systems.

Although HSBC had been collaborating with large cloud providers since 2021, specifically with Google Cloud and Amazon Web Services (AWS), by 2022, the bank had significantly increased the number of relationships with these companies. These new partnerships furthered HSBC's hybrid model of using private cloud-based systems for handling sensitive information and scalable public cloud based systems for use with analytics, customer facing platforms, etc. (HSBC, 2022). Additionally, the bank recognized cloud as a key enabler of effective data management and real-time analytics, especially in relation to compliance and regulatory reporting. There are many academic studies, including those conducted by Cheng et al., (2022), that note cloud technology is not only a tool used to enhance efficiency; however, cloud is a strategic base for the deployment of other advanced technologies such as artificial intelligence.

In its 2023 annual report, HSBC indicated that it had made significant advancements in integrating cloud-based technology into the operational aspects of the bank. Specifically, payments processing infrastructure, global risk management and customer-facing platforms were being migrated to hybrid cloud environments (HSBC, 2023). As the bank continued to expand the use of cloud-based technologies to support mission-critical operations, HSBC emphasized the importance of ensuring the security and resiliency of those technologies. Additionally, HSBC emphasized its focus on compliance with regulations specific to each of the jurisdictions in which it operates. Similar to many other banks and financial institutions, Hon and Millard (2018), argue that regulatory frameworks play a role not only in shaping the

rate at which cloud-based technologies are adopted, but also the architectural design of those technologies.

In its 2024 annual report, HSBC reported that it had made considerable advancements in deploying cloud-based solutions across all facets of its global business. Specifically, the bank's hybrid cloud-based platforms were being utilized to support the development and implementation of AI-based compliance monitoring tools, personalized digital services and cross-border transaction capabilities (HSBC, 2024). The bank's narrative on the use of cloud-based technologies was not limited to highlighting their use as a tool for modernizing traditional banking processes, but emphasized the use of cloud as the structural backbone for developing innovative products and services that can be scaled to meet the needs of diverse markets. Scholars such as Douglas and Christian (2024), argue that the convergence of cloud-based technologies and AI represents the industrial backbone for the financial services industry and will enable banks and other financial service providers, such as HSBC, to develop and deploy real-time, adaptable and data-intensive applications globally.

Overall, HSBC's transition from piloting cloud-based technologies in 2021 to implementing an enterprise wide hybrid cloud strategy in 2024 represents a strategic shift from using digitalization as a tool to improve the operational efficiency of the bank to deep tech integration to support the ongoing development of the bank's transformation strategy. Due to HSBC's global reach, the bank is required to continually balance innovation with operational and regulatory risks. While these factors may present challenges, they do not hinder the bank's use of cloud-based technologies as a fundamental component of its transformation strategy due to the bank's size and scope of operation.

Table 12 HSBC Cloud Computing Initiatives

Year	Key Cloud Initiatives
2021	Framed cloud adoption as part of modernization and efficiency strategy. Investments in infrastructure, cybersecurity, and early cloud workload migration.
2022	Expanded partnerships with Google Cloud and AWS. Advanced hybrid model combining private cloud for sensitive data with public cloud for analytics and customer services.
2023	Scaled cloud integration into mission-critical workloads (payments, risk management, customer platforms). Strong emphasis on cybersecurity and regulatory compliance.
2024	Cloud embedded across global operations. Hybrid platforms supporting AI-driven compliance, personalization, and cross-border digital services.

Source: HSBC (2021), HSBC (2022), HSBC (2023), HSBC (2024)

2.8 Analysis of HSBC's Integration of Artificial Intelligence and Cloud Computing Using Analytical Criteria Dimensions

The integration of artificial intelligence and cloud computing at HSBC reflects a gradual but deliberate adoption of deep technologies, shaped strongly by European regulatory and cultural frameworks. The following analysis applies the analytical criteria dimensions outlined in this study to assess HSBC's strategic direction.

Innovation & Value Creation

- Raising industry factors: HSBC bank increases investments in AI driven compliance elements such as, AML,KYC, fraud detection. It enables benchmark setting across Europe
- Lowering industry factors: Reduced need of old legacy systems. Reducing branch heavy operations by optimizing digital and hybrid models
- Eliminating obsolete practices: moved away from fragmented and complicated compliance monitoring systems, consolidating reporting through AI enabled analytic and telemetry.
- Creating new practices: AI driven chatbots and generative AI for documentation have been introduced, reshaping customer interaction and internal operations.

Conclusion: HSBC has demonstrated improved efficiency through the implementation of AI and cloud based solutions, and has initiated efforts to incorporate ESG considerations into their decision-making processes. However, HSBC has yet to demonstrate a commitment to sustainability, and thus leaves open questions regarding whether HSBC's transformation represents a long-term deep-tech strategy, or merely a regulatory driven modernization process (Aqmala et al., 2025).

Technological Depth & Maturity

- Cloud scalability: In order to grow globally, cloud scalable partnerships were established with Google Cloud and AWS. The adoption rate of hybrid solutions has been much lower outside of the US than inside the US.
- AI integration: Ai is being used throughout the organization, primarily within compliance, transaction monitoring, and customer experience/personalization. It will be a slow progression into using Generative Ai for operational purposes.
- Technology readiness levels: While there are AI based products being deployed on an incremental basis at HSBC, they have yet to achieve technology readiness level of full-scale transformation via deep-tech methods.

- Governance and security: HSBC's strong adherence to European Union's General Data Protection Regulation (GDPR) and other financial regulations demonstrates a high level of governance maturity. Unfortunately, this has limited the organization from exploring new forms of experimental innovation as well as moving rapidly to market with new deep-tech innovations.

Conclusion: HSBC has demonstrated significant technical depth; however, it is limited by the restrictive nature of European regulatory environments. Therefore, HSBC's adoption of new technologies has been more cautious than many of its global competitors (Hon & Millard, 2018; Cheng et al., 2022), thus demonstrating a higher level of risk aversion regarding the application of deep-tech methods for transformative innovation.

Knowledge & Ecosystem

- R&D intensity: The current R&D is focused on applied problem-solving as opposed to fundamental, long-term, or "deep" tech research.

- IP strategy: HSBC has an IP strategy that focuses on partnership and collaboration with large scale service providers such and fintech companies versus creating its own proprietary innovations

- Partnerships: effective implementation of services; however, it also limits HSBC's ability to retain ownership of the proprietary, "deep" tech intellectual property related to these services.

Conclusion: HSBC can leverage external ecosystems successfully. However, this success is contingent upon the use of partnerships that limit HSBC's ownership of deep-tech intellectual property, and therefore limit the ability for HSBC to pursue a standalone deep-tech strategy (European Commission, 2022).

Impact & Sustainability

- Efficiency: Eenhanced through better AI and Cloud use for fraud detection and compliance monitoring which will lead to reduced costs associated with operational risk.

- ESG integration: HSBC has been successful in integrating ESG in lending and investment portfolios; however, it has not utilized AI in an extensive manner to provide ESG scoring or track sustainability.

- Sustainable cloud: Energy efficient hybrid cloud operations are supported through the use of large scale AI technology; however, there are unaddressed environmental impacts from the large scale use of AI.

Conclusion: HSBC has demonstrated efficiency and has aligned itself with ESG initiatives in its early stages; however, sustainability is largely aspirational as opposed to being fully integrated within its operating model. The implications for HSBC's transformation are twofold in that it raises questions regarding if HSBC's transformation constitutes a long-term deep-tech strategic plan or simply a regulatory compliant modernization plan (Aqmala et al., 2025).

HSBC also provides evidence that European banks utilize deep-tech innovations due to the dual pressures of regulatory compliance and customer expectations. HSBC's AI and cloud utilization is systematic, globally inclusive, and based on scientific principles; however, HSBC utilizes AI and cloud at a much slower rate and more conservatively than the U.S.-based model of JPMorgan. The focus of compliance driven innovation by HSBC further illustrates a distinct trajectory of European bank adoption of deep-tech: a resilience based approach; a transparency based approach; a regulation based approach; however, this is less transformative than other models in relation to transforming customers' experiences.

2.9 Artificial Intelligence and Cloud Computing integration Analysis: Danske Bank case

Danske Bank is one of the biggest banks in the Nordic countries, with a total asset value of approximately DKK 3.7 trillion in 2024 (Danske Bank, 2024) operating primarily in Denmark, Sweden, Norway, and Finland with over three million customers. In recent years, Danske has transformed from a broad-based universal bank into a more focused Nordic bank focusing on its position as an important part of the Nordic banking system.

While Danske Bank is smaller than its main competitors within the Nordics, Nordea, SEB and Swedbank in terms of size, its focus on digitalization and customer advisory services have been emphasized as the most important areas of growth for the bank. In January 2023, Danske launched its Forward '28 strategy that includes a renewed commitment to digitalization, customer-centric service delivery, and sustainability including a number of specific targets related to profitability, efficiency, and the distribution of excess capital (Danske Bank, 2023).

The bank has identified digitalization and IT investments as a major area of focus and the bank has stated that while it will be investing less than many global banks (e.g., JPMorgan Chase or HSBC), it intends to differentiate itself in the Nordic market by being at the forefront of the application of artificial intelligence enabled customer interactions and the development of modernized hybrid-cloud infrastructures. As such, Danske Bank represents an interesting

case study for understanding how widespread the adoption of deep technology is in small but highly developed banking systems and how local regulatory environments and high levels of customer expectation influence the pace of digital innovation.

As a result, Danske Bank represents a different type of AI and cloud adoption story; while large US and global banks utilize their massive scale to pilot and deploy deep tech solutions that create new industry-wide standards, Nordic banks like Danske show how a strategic focus on customer relationships, sustainability goals, and high levels of customer satisfaction can drive adoption of AI and cloud technologies in regional contexts.

Table 13 Danske Bank Technology and AI/Cloud Investments

Year	Technology Investment (DKK billion)	AI & Cloud Focus
2021	Approx. 3.5	AI used in fraud detection, customer service chatbots; early hybrid cloud migration.
2022	Approx. 3.8	Expansion of AI in credit scoring and compliance; stronger focus on cybersecurity; cloud modernization.
2023	Approx. 4.0	Launch of Forward ’28 strategy; AI integrated into customer advisory tools and risk management; partnerships for cloud scaling.
2024	Approx. 4.2	Enterprise-wide AI adoption including generative AI pilots; hybrid cloud embedded across Nordic operations.

Source: Danske Bank (2021), Danske Bank (2022), Danske Bank (2023), Danske Bank (2024)

2.9 Danske Bank’s Implementation of Artificial Intelligence

The Danish banking leader - Danske Bank's embrace of artificial intelligence demonstrates the Nordic banking tradition of ongoing digitalization driven by favorable regulatory environments and a focus on delivering innovative customer experiences. While Danske Bank is significantly smaller than international giants like JPMorgan or HSBC, the AI initiatives of the Bank over the period 2021 - 2024 demonstrate a transition from an early stage of developing AI related compliance tools to a more developed level of creating AI-based applications directly accessible to customers.

In 2021, Danske Bank focused on AI capabilities used to identify potential fraud and monitor compliance in relation to the bank's digital infrastructure modernization process. In addition, the annual report of the Bank stated the increasing importance of AI-driven chatbots in supporting customer service and the aggregation of data sources needed to create the foundation for future machine learning applications (Danske Bank, 2021). The reliance of

Danske Bank on AI in managing risk is consistent with research conducted by Kaur et al. (2020), which indicates that predictive models are among the first and most significant applications of AI in customer analytics and fraud prevention within financial services.

By 2022, AI tools had become a central component of several critical processes of Danske Bank including credit scoring, KYC checks and AML systems (Danske Bank, 2022). The use of AI in these areas supports research conducted by Cheng et al. (2022), which states that banks generally implement AI to support the compliance requirements of regulatory agencies and simultaneously improve operational efficiency. Additionally, Danske's use of predictive analytics to enhance the accuracy of credit models is consistent with a broader industry trend of utilizing AI to mitigate borrower default risks.

In 2023, in conjunction with the launch of the Forward '28 strategy, Danske positioned AI as a mechanism for improving customer experience through the development of AI-driven robo-advisory tools and predictive analytics to deliver personalized financial guidance. In addition, the Bank utilized AI to optimize portfolio management to further enhance investment services (Danske Bank, 2023). Similar to the research conducted by Mancuso et al. (2025), the development of AI-driven robo-advisory tools and predictive analytics enabled the transformation of the drivers of value creation in banking through the delivery of personalized and scalable solutions to customers. At the same time, Maple et al. (2023) warn that while personalization can increase engagement, it can also generate concerns related to the presence of bias in algorithms and the lack of explainability of these biases. These concerns have the potential to negatively affect customer trust if not appropriately addressed.

In 2024, Danske Bank reported testing the application of generative AI in several new areas including document processing, regulatory reporting and customer advisory functions (Danske Bank, 2024). This marked a movement from incremental improvements in operating efficiency to a greater integration of AI into the strategic decision-making processes of the Bank. According to Douglas and Christian (2024), this integration of AI with digital infrastructures is a key element in the implementation of large-scale industrial transformations. However, they also point out that the integration of AI with digital infrastructures presents many governance and operational risk challenges. The move by Danske Bank to incorporate generative AI is a clear indication of the Bank's commitment to deep-tech trajectories; however, the relatively small scale of the Bank compared to larger global banks demonstrates the challenge faced by smaller institutions in fully leveraging the benefits of these technologies.

In general, the AI strategy of Danske Bank illustrates both the opportunities and the limitations associated with the adoption of deep-tech in a Nordic country. The progressive nature of the Bank's AI adoption demonstrates that AI can be successfully integrated into compliance, risk management and customer service initiatives. However, the path of adoption also highlights limitations, including scale, dependence on third-party technology ecosystems

and unresolved issues surrounding algorithmic transparency and fairness. As noted by the European Commission (2022), achieving true deep-tech transformation will require not only the successful implementation of technologies but also the establishment of effective governance structures and system-wide resilience. While Danske's initiatives demonstrate progress, the overall impact is more incremental than systemic and position the Bank as a regional innovator rather than a global leader in AI adoption.

Table 14 Danske Bank AI Initiatives 2021-2024

Year	Key AI Initiatives
2021	AI applied in fraud detection and compliance monitoring; expansion of AI-driven chatbots for customer service.
2022	AI integrated into credit scoring, KYC/AML monitoring, and predictive analytics for credit risk assessment.
2023	Launch of Forward ’28 strategy; AI-driven robo-advisory and predictive analytics for retail customers; portfolio management support.
2024	Generative AI pilots for document processing, regulatory reporting, and personalized customer advisory services.

Source: Danske Bank (2021), Danske Bank (2022), Danske Bank (2023), Danske Bank (2024)

2.10 Danske Bank’s Implementation of Cloud Computing

Danske Bank’s cloud migration process represents both a desire to transform banking through technology, and the restrictions on banking operations imposed by regulation within the European Union. Between 2021 and 2024 Danske Bank developed a hybrid cloud model which provides a balance between scalability and compliance; cloud has become integral to many of Danske Bank’s core banking services.

In 2021, the Annual Report stated that cloud computing would be one of the key foundations to enable digital transformation. The focus was to move non-mission critical workloads to the cloud, enhance security and ensure that the bank was compliant with EU Data Protection Regulations (Danske Bank, 2021). This incremental use of cloud computing is similar to what Vinoth et al. (2022) identified as a cautious but necessary stage for all banks. Banks deploy cloud initially to enhance disaster recovery and business continuity prior to extending it to mission critical processes.

By 2022, Danske Bank had strengthened their partnership with Microsoft Azure, indicating that cloud computing will be used to enhance customer service delivery, data management, and scalability (Danske Bank, 2022). Like other banks, compliance remains a central element to these cloud projects and are consistent with Cheng et al. (2022) who assert that cloud computing can support two main objectives for banking organizations: efficiency and developing future capabilities such as Artificial Intelligence.

By 2023, cloud computing became a major component of Danske Bank's Forward '28 strategy, outlining cloud computing as a means to deliver greater efficiency and innovation. Cloud migration expanded to include core banking functions allowing real time analytics and enhanced advisory services (Danske Bank, 2023). The bank also highlighted a desire to collaborate closely with fintech companies, illustrating Mancuso et al. (2025) assertion that digital ecosystems provide banking organizations with the capability to develop innovative products and services externally to their own R&D capabilities. However, as Hon and Millard (2018) illustrate, relying on third party cloud providers increases the complexity associated with meeting legal and regulatory requirements, particularly in international financial services.

By 2024, Danske Bank indicated that cloud computing was now embedded throughout their global operation. Their hybrid cloud models were now supporting generative AI applications, cross border payment processing and sophisticated fraud detection (Danske Bank, 2024). The bank also indicated that their cloud infrastructure was supporting sustainability goals, as the concentration of resources onto cloud based platforms has resulted in a lower carbon footprint for their IT activities. This supports the assertions made by Aqmala et al. (2025) that sustainability and innovation are becoming increasingly aligned in banking strategies, and that cloud computing and AI are now forming a significant component of ‘green’ digital transformation.

In total, Danske Bank’s cloud migration illustrates a transition from cautious experimentations with cloud to integrating cloud into core banking systems. Cloud is being positioned as a tool to modernize banking and to enable the development of advanced digital capabilities including generative AI, advanced analytics and sustainability objectives. Challenges still exist however. As Danske Bank relies on large international cloud providers (such as Microsoft), they create strategic dependencies, whereas the requirement to comply with EU regulations restricts their ability to adapt to changing circumstances. Similar to the European Commission (2022) statement, Danske Bank’s approach to cloud computing demonstrates elements of deep-tech transformation, however, due to the smaller size of the organization compared to the largest global players, Danske Bank are acting as a regional leader, applying deep-tech innovations to the heavily regulated banking industry.

Table 15 Danske Bank Cloud Computing Initiatives 2021-2024

Year	Key Cloud Initiatives
2021	Early migration of non-critical workloads; modernization of IT infrastructure; strengthened cybersecurity.
2022	Expanded partnerships with Microsoft Azure; hybrid adoption for scalability and data management; strong compliance focus.

2023	Forward ’28 strategy emphasized cloud for efficiency and innovation; migration of core banking functions; support for real-time analytics and fintech integration.
2024	Hybrid cloud fully embedded; platforms supporting generative AI, cross-border payments, and fraud detection; focus on sustainability and energy efficiency.

Source: Danske Bank (2021), Danske Bank (2022), Danske Bank (2023), Danske Bank (2024)

2.11 Analysis of Danske Bank’s Integration of Artificial Intelligence and Cloud Computing Using Analytical Criteria Dimensions

The integration of artificial intelligence and cloud computing at Danske Bank demonstrates how a Nordic financial institution pursues deep-tech adoption in a smaller but highly digitalized market. The following analysis applies the analytical criteria framework to evaluate how effectively Danske leverages AI and cloud technologies.

Innovation and Value Creation

- Danske utilized AI-based compliance monitoring, predictive analytics, and robo-advisory tools, thus increasing the standard of digital banking service within the Nordic Region (Danske Bank, 2022, 2023).
- Lowering industry factors: By transitioning workload to Hybrid Cloud Platforms, the Bank eliminated its reliance on Legacy IT Infrastructure reducing costs and increasing efficiencies (Danske Bank, 2022).
- Eliminating obsolete practices: Data Systems have been transitioned to Integrated Cloud Supported Infrastructures, the Bank has created the capability for Real-Time Reporting and Customer Analytics (Danske Bank, 2023).
- Creating new practices: The Generative AI Pilots for Document Processing and Customer Advisory Services demonstrate the ability to create new functionalities that go beyond typical Banking Functions (Danske Bank, 2024).

Conclusion: Although the scope of Danske Banks efforts remain limited in comparison to larger global competitors, Danske Bank has altered value creation through strategic use of AI and Cloud Technologies. Danske's Strategy is aligned with

Kim and Mauborgne (1999, 2005) and creates a solid foundation for further industry impact however the current resource constraints will limit this potential.

Technological Depth and Maturity

- Cloud scalability: The hybrid cloud model used for payment processing, fraud detection, and customer analytics will be adopted by 2024 (Danske Bank, 2024), demonstrating the increasing maturity of cloud computing technology within Danske Bank.
- AI integration: Within a period of three years, AI technology has developed significantly beyond its early application in the fields of fraud detection and Know Your Customer (KYC) monitoring; it is now being applied in predictive analytics and pilot projects involving generative AI (Danske Bank, 2021 – 2024).
- Technology readiness levels: Although implementation has reached an applied level of maturity, there is a lack of investment in proprietary development of technologies, indicating that Danske Bank is reliant on other organizations for access to new or emerging technologies (Danske Bank, 2024).

- Governance and security: Regulatory compliance with the EU's regulatory frameworks has been emphasized repeatedly throughout the report, and this demonstrates that Danske Bank recognizes and understands the potential risks associated with their reliance on cloud-based technology and the requirements of data localization regulations (Danske Bank, 2022).

Conclusion: incremental deep-tech transformation undertaken by Danske Bank represents an example of how cloud and AI can be employed to improve both the resilience and operational efficiencies of banking services; however, these benefits are offset by increased dependence on third-party organizations and, subsequently, decreased long-term autonomy (Hon & Millard, 2018).

Knowledge and Ecosystem

- R&D intensity: Danske's investments are largely focused on applied AI and digital services, with limited emphasis on fundamental R&D.
- IP strategy: Proprietary intellectual property remains limited, as innovation is primarily achieved through partnerships.
- Partnerships: Collaborations with Microsoft Azure and fintech companies enhance speed of adoption but dilute control over technological knowledge.

Conclusion: The bank demonstrates strong reliance on ecosystems, which aligns with Mancuso et al. (2025), but this comes at the expense of independent innovation capacity. As the European Commission (2022) notes, such dependence raises questions about whether Danske fits a systemic deep-tech model or a hybrid approach.

Impact and Sustainability

- Efficiency: AI improved fraud detection, compliance monitoring, and customer personalization, contributing to stronger efficiency ratios (Danske Bank, 2023).
- ESG integration: Cloud migration was linked to reduced IT environmental footprint, yet AI for ESG scoring and green finance innovations remain underdeveloped (Danske Bank, 2024).
- Sustainable cloud: Hybrid solutions optimized energy use, but systemic sustainability of AI adoption has not yet been demonstrated.

Conclusion: Danske Bank has implemented measurable efficiencies through use of AI and cloud technology. However, at this time Danske's ESG is still an emerging area within deep-tech.

While Danske Bank may be considered a hybrid or regional deep-tech bank due to its incorporation of AI and cloud technologies to enhance its compliance, customer experience and operational capabilities; and its overall deep-tech strategy, it lacks significant resources to support its own R&D and relies heavily on outside vendors for many of its systems and applications which limits its ability to be classified as a fully developed deep-tech bank.

2.12 Comparative Comparison of AI and Cloud Strategies as Deep-Tech Drivers in the Banking Sector

After analysing the three selected cases - JPMorgan Chase, HSBC, and Danske Bank - an comparative evaluation can now be made across the analytical dimensions introduced earlier in this study. The purpose of this comparison is to identify how each institution approaches deep-tech adoption through AI and cloud computing, and to what extent they reshape value creation and delivery in the banking sector. The table below summarizes the findings for the first dimension, Innovation & Value Creation.

Table 16 Comparative evaluation of Innovation & Value Creation in JPMorgan, HSBC, and Danske Bank

Value loop question	**JPMorgan Chase**	**HSBC**	**Danske Bank**
Which factors should be reduced below industry standard?	Reduced dependency on costly legacy IT systems and physical infrastructure	Lowered reliance on legacy IT systems and branch-heavy operations	Reduced reliance on legacy IT infrastructure by migrating to hybrid cloud
Which factors should be raised above industry standard?	Significantly increased technology spending above peers.	Raised standards in AI-driven compliance and fraud detection	Enhanced AI-driven compliance monitoring, predictive analytics, and robo-advisory tools
Which industry practices should be eliminated?	Eliminated traditional siloed data management, replacing it with scalable, consolidated architectures	Abandoned fragmented compliance monitoring systems by consolidating reporting into AI-enabled analytics.	Phased out siloed data systems, replacing them with integrated cloud infrastructures enabling real-time analytics and reporting
What new elements should be created?	Introduced generative AI initiatives in compliance, trading optimization, and personalized services	Implemented AI-driven chatbots and generative AI tools for documentation, reshaping both customer interaction and internal processes.	Developed generative AI pilots for document processing and customer advisory services, creating new capabilities beyond conventional functions

Source: compiled by author, accordint to data from 2021-2024 Annual report of HSBC, Danske Bank, JP Morgan

The comparison of the three banks shows how each bank uses Kim and Mauborgne's (1999, 2005) value innovation logic to both create new and eliminate old industry practice and to reduce or increase existing ones. JPMorgan is focused on using large amounts of technology funds and AI to innovate at the expense of other competitors; however, HSBC has taken an approach that primarily innovates through improving compliance efficiency and regulatory resiliency. Additionally, Danske Bank has also used this strategy but at a much smaller scale to improve customer advisory tools and predictive analytics for customers in their region. Together, these cases show different approaches to strategically use AI and cloud computing as deep-tech enablers, with U.S. and U.K. banks having greater impact globally than the Danish bank which is a prime example of regional specialization.

To evaluate the selected banks based on the level of technological maturity, including cloud scalability, AI integration, and their readiness levels and governance, may help to establish a baseline for comparing the maturity of the three banks.

Table 17 Comparative evaluation of Technological Depth & Maturity in JPMorgan, HSBC, and Danske Bank

Dimension	JPMorgan Chase	HSBC	Danske Bank
Cloud scalability	Expanded hybrid cloud with AWS and Azure, covering mission-critical operations such as trading and risk management.	Partnerships with Google Cloud and AWS; global scaling slower due to regulatory caution.	Hybrid cloud adoption supported payments, fraud detection, and customer analytics by 2024.
AI integration	Enterprise-wide AI integration in compliance, fraud detection, productivity, and customer services.	AI embedded in compliance and personalization, expanding into generative AI for operations.	AI progressed from fraud detection and KYC toward predictive analytics and generative pilots.
Technology readiness levels	Deployment at enterprise-wide scale, though reliance on external providers limits ownership.	Deployment remains partial and incremental rather than transformative.	Applied maturity visible, but limited proprietary development creates dependency.
Governance and security	Strong cybersecurity and compliance frameworks, with risks tied to multi-tenancy and localization.	High compliance maturity under GDPR, but restrictive for experimental innovation.	Compliance-driven governance emphasizes resilience under EU regulatory frameworks.
Assessment	Deep-tech transformation with scale and embedded AI, though autonomy risks persist.	Technological depth present, but innovation is more incremental and regulation-driven.	Incremental deep-tech trajectory improving efficiency, yet constrained by external reliance.

Source: compiled by author, accordint to data from 2021-2024 Annual report of HSBC, Danske Bank, JP Morgan

The comparisons show that JP Morgan has the most advanced trajectory for using artificial intelligence and Hybrid Cloud at a high level of sophistication, as well as at scale, in all of its "mission critical" business functions; HSBC has a high level of technological depth, however, HSBC does not apply it as widely as JP Morgan because of regulatory constraints in Europe; and Danske Bank uses a "regional adaptation" strategy, which combines the use of applied AI, hybrid cloud, and robust governance, but, unlike JP Morgan and HSBC, Danske Bank is severely constrained in its ability to control its own "core systems." Together, the three case studies demonstrate how there can be a trade-off between deep technology transformation and the degree of external dependence in large-scale international versus smaller regional banking models.

The comparisons among JPMorgan, HSBC and Danske Bank relative to knowledge creation, intellectual property and ecosystem leverage are shown in the following table.

Table 18 Comparative evaluation of Knowledge & Ecosystem in JPMorgan, HSBC, and Danske Bank

Dimension	JPMorgan Chase	HSBC	Danske Bank
R&D intensity	Large-scale investment, mainly applied deployment rather than fundamental research.	Focus on applied technology rather than deep R&D.	Investments concentrated on applied AI and digital services.
IP strategy	Ecosystem-driven innovation, limited proprietary patents in AI or cloud.	Relies on hyperscale providers and fintech collaborations, little proprietary IP.	Proprietary IP limited, with reliance on ecosystem partnerships.
Partnerships	Collaborations with AWS, Microsoft, fintechs, and universities.	Strong alliances with cloud providers and RegTech firms.	Collaborations with Microsoft Azure and fintechs.
Assessment	Hybrid deep-tech model, distributing knowledge across internal and external actors.	Collaborative model of innovation, ecosystem dependence outweighs proprietary ownership.	Ecosystem-driven adoption enhances agility but limits independent innovation capacity.

Source: compiled by author, accordint to data from 2021-2024 Annual report of HSBC, Danske Bank, JP Morgan

JPMorgan, HSBC, and Danske Bank all rely heavily on partnerships with hyperscale providers and fintechs, which accelerates implementation but dilutes proprietary ownership. While JPMorgan invests the most in applied technology, it remains dependent on external ecosystems for fundamental breakthroughs. HSBC's collaborative strategy emphasizes regulatory alignment, whereas Danske's hybrid model reflects both regional limitations and agility. Collectively, the findings indicate that banks increasingly adopt a distributed innovation model where ecosystems substitute for in-house deep-tech R&D.

Evaluating the three banks by efficiency, ESG integration, and sustainable cloud adoption can be seen in the table below.

Table 19 Comparative evaluation of Impact & Sustainability in JPMorgan, HSBC, and Danske Bank

Dimension	JPMorgan Chase	HSBC	Danske Bank
Efficiency	AI-driven automation improves compliance, fraud detection, and contract review.	Fraud detection and compliance monitoring gains improve operational efficiency.	Fraud detection, compliance, and personalization strengthen efficiency ratios.

ESG integration	ESG-linked lending present, but AI-driven ESG scoring underdeveloped.	ESG integrated into lending and investments, though AI use in ESG still emerging.	Cloud migration reduced IT footprint, but AI for ESG and green finance remain limited.
Sustainable cloud	Hybrid cloud enhances efficiency, but large AI models raise environmental concerns.	Hybrid cloud supports energy-efficient operations, though AI costs remain high.	Hybrid solutions optimized energy use, but systemic sustainability not yet proven.
Assessment	Strong efficiency gains, partial ESG adoption, unresolved environmental costs.	Efficiency and ESG alignment growing, but more regulatory-driven than transformative.	Efficiency improvements achieved, but ESG and sustainability integration still modest.

Source: compiled by author, according to data from 2021-2024 Annual report of HSBC, Danske Bank, JP Morgan

AI and Cloud Adoption Has Created Measurable Efficiency Gains Across All Three Institutions, Especially In Compliance, Fraud Detection, and Customer-Facing Processes; However, ESG Integration Is Partial With Most Initiatives Focusing On Lending and Portfolio Management Rather Than AI-Driven Sustainability Metrics. Large-Scale AI Operations Produce Environmental Costs That Are Obstacles to Both JPMorgan and HSBC, While Hybrid Cloud Has Allowed Danske To Achieve Modest Progress in Energy Use Optimization. As Such, Sustainability Remains An Emerging Dimension of Deep-Tech Banking Transformation Rather Than A Fully Embedded Strategic Driver.

After Reviewing the Selected Banks Through the Dimensions of AI and Cloud Adoption Using the Deep-Tech Framework It Became Apparent That All Three Institutions Represent Characteristics Of Deep-Tech and Have Made Significant Optimizations of Their Banking Operations. JPMorgan Represents the Highest Level of Maturity and Technological Development Among the Three Institutions and Serves as a Benchmark For Global Transformation. Conversely, HSBC and Danske Bank Represent Gradual But Meaningful Progress Toward Deep-Tech Integration Beyond Simple Digitalization.

Overall, If Globally Recognized Banking Cases Align With the Deep-Tech Criteria of AI and Cloud Adoption, These Cases Can Be Used as a Reliable Reference Point For Evaluating Technological Transformation Within the Sector. Additionally, the Analyzed Banks Provide a Solid Foundation Upon Which Further Qualitative Research Can Be Conducted, i.e., Expert Interviews. An Expert Survey Conducted Subsequent to This Analysis Could Reinforce the Argument That the Identified Deep-Tech Dimensions Are Not Only Valid For the Selected Cases But Also Valid for More Broad-Based Assessments of Deep-Tech Transformation of Banking Institutions.

3. RESEARCH ON APPLYING QUALITATIVE CRITERIA TO EVALUATE AI AND CLOUD INNOVATION FOR CORE FINANCIAL OPERATIONS IN BANKING

Both quantitative and qualitative research methodologies have been researched for this study. Quantitative research methodologies can provide an advantage over other methodologies if the aim of the study is to test established theory or measure existing constructs. According to Creswell, J. W and Creswell J. D (2018) quantitative research studies rely on mathematical and statistical analysis that can present data in numerical form, most commonly through tables or graphs. A quantitative approach typically requires a large number of participants and utilizes structured tools such as close ended questionnaires. Accessing a sufficient population of participants with appropriate experience and trustworthiness in the area of AI and Cloud innovations in Banking may also prove difficult due to limited access to professionals who meet these criteria.

Consequently, this study will use a qualitative approach. Qualitative methods allow researchers to develop a deep understanding of an issue, concept, or phenomenon, which makes them better suited to studying how organizations apply AI and cloud technology within their core operational functions. Creswell, J. W and Creswell J. D (2018), states that qualitative studies are ideal when researchers seek to explore concepts or generate new theories instead of testing existing ones. In this case, the researcher will collect data from a limited number of carefully selected subject matter experts using open-ended questionnaires to provide for the capture of rich descriptions of individual perspectives. Denzin and Lincoln (2018) further state that qualitative research seeks to understand the meanings people create about the world around them and to recognize the importance of context, and to interpret the ways in which people make sense of events in their lives. This emphasis on meaning making, context, and interpretation allows researchers to gain a deeper understanding of complex processes like technological disruption in banking. Additionally, Patton (2015) has highlighted the power of qualitative research methods in applied research, specifically when the goal of the research is to gather the judgments of experts; to identify the experiences of diverse populations; and to describe emergent practices.

For this study a qualitative methodology was chosen, employing a questionnaire with eleven items (see Table 20), administered to experts, with opportunity for follow-up on any unclear question. The questionnaire follows general best practices drawn from leading qualitative research texts. According to Creswell & Poth (2018) and DeMarrais, et al. (2024), research with specialist respondents merits purposeful sampling to ensure participants have relevant experience and insight. Questions are framed clearly and concretely, avoiding double-barrelled or leading wording, and presented in logical sequence. The purpose of the

research is explained at the outset, and instructions are provided, following recommendations on instrument transparency and respondent motivation (Creswell & Poth, 2018). Approximately half of the questions are open-ended to allow for rich, nuanced feedback, consistent with guidance for exploratory qualitative work (DeMarrais et al., 2024). To ensure quality and validity, the instrument will be pilot tested, and data will be analysed through coding and thematic analysis, with member checking and reflexivity as criteria of trustworthiness (Denzin & Lincoln, 2023). Questions can be grouped into 4 categories (See Table 20)

Table 20 Survey structure

SECTION / THEME	QUESTIONS
Respondent Characteristics	• Position in the banking sector • Experience in the banking sector
AI and Cloud Technologies' Contribution to Value Creation	• To what extent do AI and Cloud contribute to value creation in core banking operations? • Please provide examples of how AI and Cloud technologies contribute to value creation for banks.
Impact on Core Banking Operations	• Which aspects of core banking are most impacted by AI and Cloud adoption, and why?
Quality and Evaluation Criteria	• How would you define a high-quality integration of deep-tech (AI and Cloud) in banking? • Which qualitative criteria should be used to evaluate the success of AI and Cloud integration in banking?
Barriers and Constraints	• What are the most pressing barriers to adopting AI and Cloud in banking? • In your opinion, how do regulatory requirements and compliance standards shape or constrain the integration of AI and Cloud in core banking operations?
Technological Nature and Future Outlook	• Do you see AI and Cloud implementation in banking as a disruptive deep-tech technology or as a gradual technological advancement? • Looking ahead, what do you believe will be the most critical success factors for the banking sector aiming to systematically integrate AI and Cloud into their core operations over the next five years?

Source: compiled by author

It is evident that questions in the questioner are related to AI and Cloud Innovations in banking, it explores it through the lens of deep-tech and relates to the issues described in theoretical part of this work

Goal of the research - to gather expert knowledge on the application of deep-tech innovations in banking and to determine how core financial operations can be enhanced through the integration of Artificial Intelligence and Cloud technologies. The study aims to

identify the main challenges that arise in the process of integrating these technologies, to distinguish cases of successful implementation, and to establish qualitative criteria for measuring the success of deep-tech adoption within the banking sector. On the basis of the evaluation results, a framework will be proposed for addressing the most significant barriers to AI and Cloud integration in banking.

Research Objectives

1. To investigate expert opinions on whether Artificial Intelligence and Cloud innovations contribute to value creation in core financial operations of banks.
2. To explore how deep-tech driven approaches, such as AI-Cloud integration, can be systematically applied to optimize financial processes.
3. To define the concept of quality in banking operations in the context of AI and Cloud adoption.
4. To identify the most important qualitative criteria for evaluating the effectiveness of AI and Cloud innovations in banking.
5. To examine the main challenges and barriers encountered when implementing AI and Cloud technologies in core financial services.
6. To assess expert views on whether AI and Cloud adoption in banking institutions represents a strong example of deep-tech transformation.
7. To identify and distinguish best-practice cases of AI and Cloud innovation in the banking sector that can serve as benchmarks for future implementation.
8. To develop a framework that addresses the challenges of AI and Cloud integration in banking, based on the evaluation of qualitative criteria.

Object of the Research - The application of Artificial Intelligence and Cloud innovations in optimizing core financial operations in the banking sector.

Organization of the Research

The study took place over two weeks, beginning with 22 Sep and concluding 15 Oct. Employees working within the banking industry completed a questionnaire to collect data. Nine individuals provided input as part of this study; however, 8 participants were selected for the analysis to provide a sufficient amount of variability in their answers (Figure 5).

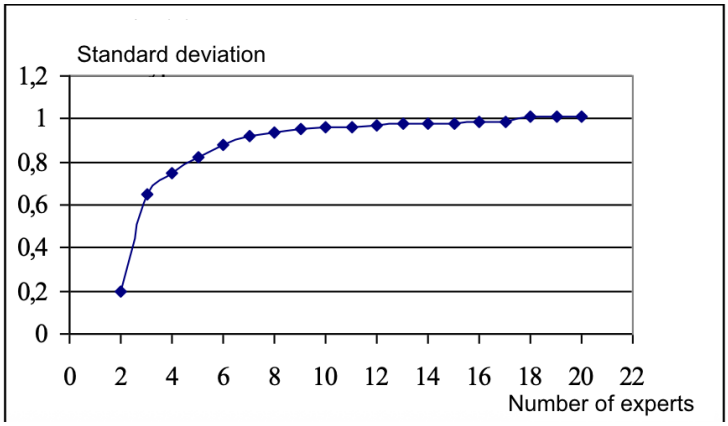
The final sample represented a diverse range of roles, including Senior Cloud Engineer (DevOps Engineer), Cloud Engineer, IT Business Analyst, Business IT Analyst, Product Owner, User Experience Designer, Senior AML Officer, and Test Automation Engineer. This

diversity ensured that the collected data reflected multiple perspectives on the application of AI and cloud technologies across different banking functions.

However, one survey was eliminated from the analysis, as participants did not fully complete questionaries and left majority of questions empty and answered vaguely. Thus, results will be analysed gathered from 8 experts. For confidentiality reasons, all participants were anonymized and coded with identifiers - P1, P2, and so on. All experts agreed to specify the occupied functions but not name of the Bank they are currently employed at. Participants were contacted personally, as well as through the corporate channels and introduced to the problem and goal of the research

Experts were selected based on criterion-based sampling, to ensure that participants possessed direct and relevant expertise regarding the integration of Artificial Intelligence and Cloud technologies in the banking sector. Criterion sampling, as Creswell and Poth (2018) emphasize, is a form of purposeful sampling that ensures all participants meet a predefined set of characteristics necessary to address the research questions. In this case, experts with experience in working with Artificial Intelligence and Cloud technologies in the banking sector.

Figure 3 Standard Deviation versus Number of experts



Source: (Baležentis & Žalimaitė, 2011)

Characteristics of survey respondents

From the correspondent who were performing in the survey, eight experts have been chosen for final analysis. First question of the survey was meant for confirming correspondents' positions. These were answers gathered:

- P1 - Senior Cloud Engineer (DevOps Engineer)
- P2 - User Experience Designer
- P3 - Senior AML Officer

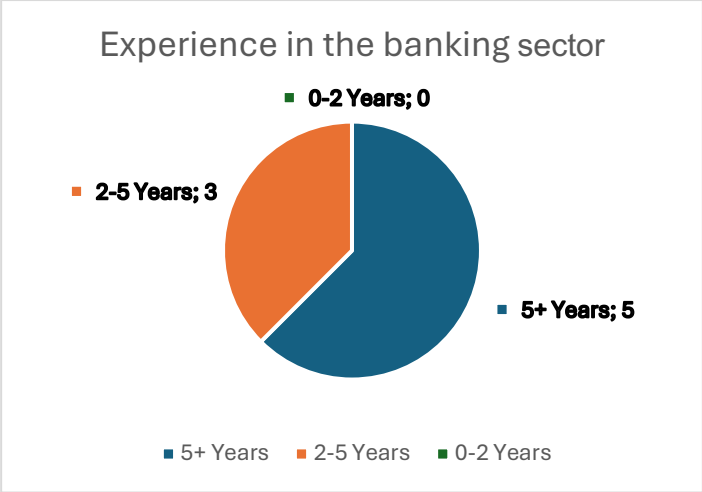
- P4 - Product Owner
- P5 - Cloud Engineer
- P6 - IT Business Analyst
- P7 - Test Automation Engineer
- P8 - Business IT Analyst

3.1 Research data analysis

After confirming correspondents' positions, second question was meant to determine experts experience in the banking sector.

Second question: Your experience in the banking sector (See figure 4)

Figure 4 - Experts experience in banking sector



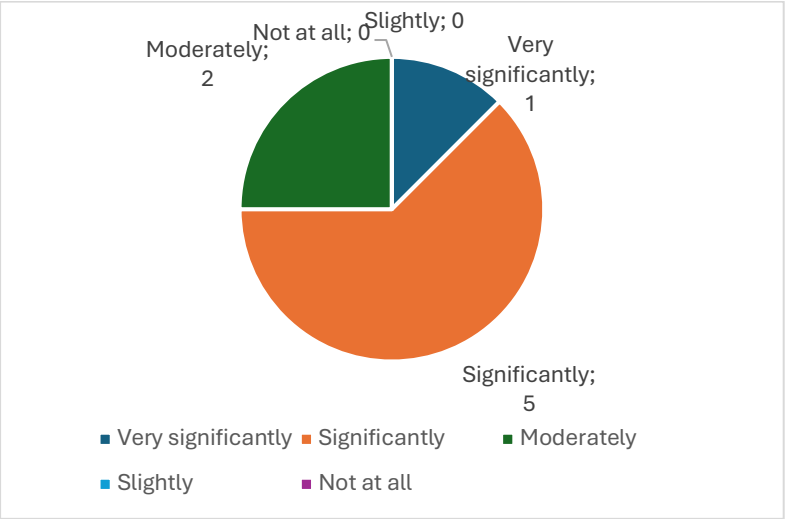
Source: compiled by author

It is seen that majority of the experts - 5 have experience of more than 5 years. Three experts have experience of 3-5 years. None of the correspondents were in 0-2 years category. Thus, it is evident that experts surveyed were experienced and represented senior experts' opinions.

Third question: To what extent do Artificial Intelligence and Cloud technologies contribute to value creation in core banking operations?

The expert responses (Figure 5) indicate strong agreement that AI and Cloud technologies significantly enhance value creation in core banking operations. These findings align with academic literature emphasizing that such technologies drive operational efficiency and innovation within the sector. Overall, the results confirm that AI and Cloud adoption contributes meaningfully to value generation in banking.

Figure 5 - Experts answers to "To what extent do AI and Cloud technologies contribute to value creation in core banking operations?"



Source: compiled by author

Fourth question: Please provide examples how AI and Cloud technologies contribute to value creation for the Banks

Table 21 Experts answers on Fourth question categorised by theme

Theme	Example from Experts	Key Insight
Operational efficiency	Experts highlighted that AI reduces manual workload and accelerates internal processes, allowing teams to focus on innovation (P1, P3, P7).	Automation of manual tasks leads to significant time and cost optimisation.
Scalability and agility	One expert explained that "Cloud makes us faster and more flexible; new environments can be launched in hours" (P4). Other participants confirmed similar experiences (P6, P8).	Cloud infrastructure enables quick product deployment and supports digital transformation.
Fraud detection and risk management	Participants stated that AI solutions enhance fraud detection and credit scoring accuracy, improving the reliability of financial systems (P3, P5, P6).	AI-driven predictive analytics strengthen security and reduce financial losses.
Customer experience	Respondents mentioned that AI chatbots and automation tools enable faster customer support and improved satisfaction (P1, P2, P4).	AI enhances service quality and customer engagement through personalised and rapid interaction.
Innovation and integration	Experts noted that cloud platforms help integrate data across departments, enabling more informed decision-making (P4, P8).	Combined use of AI and Cloud fosters innovation through data-driven insights and system integration.

Governance awareness	None of the experts explicitly addressed AI ethics or accountability, though operational and financial benefits were widely emphasised (all participants).	Ethical and governance evaluation remains underdeveloped compared to operational and financial metrics.

As seen in Table 20, finding show and support literature's view that AI and Cloud technologies are see as key drivers of value creaton in core banking processes. Futhermore, findings identify main themes - operational efficiency, scalability, fraud detection, customer experience, and innovation - align with the digital transformation factors described by Avram (2014), Hon and Millard (2018), and Cheng et al. (2022). Experts frequently cited cloud technology as enabling faster development cycles and greater flexibilit on how workload can be split. One participant explained that the Cloud "makes us faster and more flexible; new environments can be launched in hours instead of weeks," highlighting its role in accelerating product deployment (P4). Others mentioned that scalable systems maintain performance during peak transaction periods (P6, P8). Similarly, AI was widely recognised for improving compliance, fraud detection, and service delivery. Several experts stated that AI "reduces manual workloads and increases accuracy in fraud detection," freeing time for innovation and customer engagement (P1, P3, P7). Compliance specialists (P3, P5, P6) added that AI supports the detection of suspicious transactions, consistent with Mirishli's (2024) findings. Customer facing AI tools such as chatbots were also said to improve accessibility and responsiveness (P1, P2, P4). However, none of the participants raised issues of fairness or accountability, suggesting that while banks focus strongly on efficiency, ethical governance remains underdeveloped. Overall, both literature and empirical evidence indicate that AI and Cloud technologies work together to enhance scalability, accuracy, and innovation.

Fifth question: Which aspects of core banking operations (such as payments, compliance, credit risk, fraud detection, customer service, or back-office efficiency) are most impacted by AI and Cloud adoption, and why?

Survey revealed several recurring themes regarding the operational areas most affected by Artificial Intelligence and Cloud technologies. Table 21 illustrates the five main themes that emerged from the analysis, showing how both technologies jointly influence critical aspects of core banking operations. These thematic categories were derived through inductive coding of expert responses and reflect the areas where digital transformation is perceived as most tangible.

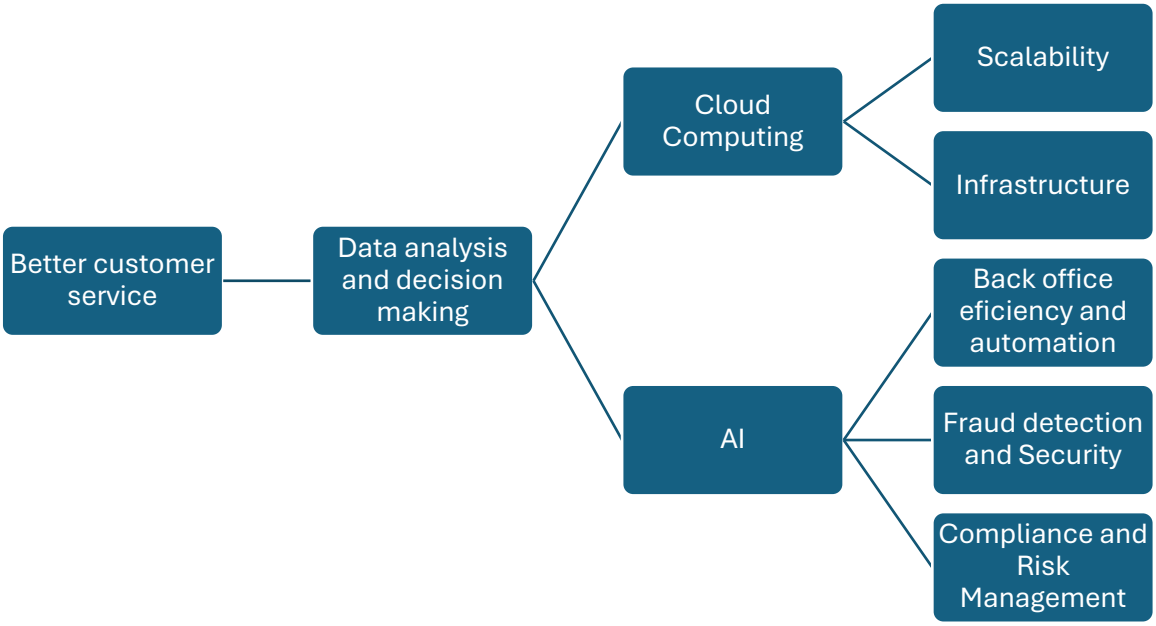
Table 22 – key themes and insights on which aspects of core banking operations are most impacted by AI and Cloud adoption, and why?

Theme	Illustrative Expert Statements	Key Insight
Compliance and Risk Management	"Compliance is a huge topic where AI can really shine and help us" (P1). "AI helps detect fraud, improve compliance checks, and reduce manual work" (P4).	AI automates compliance reporting and enhances accuracy in regulatory and credit risk processes.
Fraud Detection and Security	"Fraud detection is being improved every day with AI and Cloud" (P3). "AI helps to find patterns in customer behaviour and risks" (P6).	AI-driven analytics strengthen security through real-time detection and proactive risk monitoring.
Back-Office Efficiency and Automation	"Back-office efficiency is most impacted; new tools are introduced almost weekly" (P2). "Cloud improves back-office performance, making systems faster and scalable" (P5).	Cloud-based automation increases operational speed, reduces costs, and enhances workflow reliability.
Customer Service and Experience	"Chatbots and virtual assistants make it easier to handle routine requests 24/7" (P3).	AI enhances accessibility, responsiveness, and personalisation in customer interactions.
Data Analytics and Decision-Making	"AI and Cloud change how we manage data and customer processes; together they improve decision making" (P6).	Integration of AI and Cloud promotes data-driven decision-making and cross-departmental collaboration.

Source: compiled by author

The analysis indicates that compliance and risk management, fraud detection, back-office efficiency, customer service, and data-driven decision-making are the most substantially impacted domains. Consistent with what literature suggests (Avram, 2014; Cheng et al., 2022; Mirishli, 2024), participants described AI and Cloud as complementary tools - AI enhancing analytical and decision-making capabilities, and Cloud providing the scalability and infrastructure needed to operationalise these improvements. Compliance, credit risk, and fraud detection were viewed as high-priority areas for automation and accuracy, while Cloud-driven back-office efficiency was frequently cited as a visible and immediate improvement. These answers also mark and confirm architecural correlation between cloud computing and AI (see figure 6) that was mentioned in literature as something that extends beyond operational convenience and provides modularity, allowing AI-based innovations to be scaled across diverse banking channels (Legapriyadharshini et al., 2024).

Figure 6 Key themes correlation for aspects of core banking operations



Source: compiled by author

Sixth question: How would you define a high-quality integration of deep-tech (AI and Cloud) in banking?

Experts' responses to this question can be grouped and aggregated into key points for high-quality integration of deep-tech (Table 23)

Table 23 Main points to define high quality integration of AI and Cloud in banking as a deep tech

High quality integration aspects
High-quality integration is characterised by fully automated, streamlined processes that eliminate repetitive manual work and increase operational efficiency.
AI enables data-driven decision-making that enhances compliance, risk management, and customer insight accuracy.
Cloud computing ensures scalability, resilience, and cost-efficient resource use, supporting continuous system performance.
Integration quality depends on alignment between technological capabilities and business objectives, ensuring technology delivers measurable value.
Security, compliance, and reliability must be built into systems from the beginning to ensure stability and regulatory trust.
Successful integration requires organisational readiness and collaboration across IT and business teams.

High-quality integration is achieved when technology is practical, dependable, and improves real processes rather than serving as a novelty.

Source: compiled by author

From experts' opinions it is seen that high quality integration of AI and Cloud technologies in the banking sector is seen as the achievement of automation, scalability, and data driven decision making that align technological capabilities with business goals while ensuring security, reliability, and real operational value.

Seventh question: Which qualitative criteria should be used to evaluate the success of AI and Cloud integration in banking?

Furthermore, survey tried to identify what experts think are the qualitative criteria that could be used to evaluate the success of AI and Cloud integration in banking. After collecting answers, they were compares to evaluation criteria mentioned in Chapter 2 (see Table 5). Figure 7 illustrates frequency of key criteria selected by experts illustrating that operational efficiency, scalability and flexibility, and risk management and compliance emerged as the most frequently cited factors

Figure 7 Frequency of key qualitative criteria selected by experts

Source: compiled by author

These findings closely align with the secondary research evaluation framework developed in Chapter 2; however, it is important to empathise and put more focus on Operational efficiency as this was the most important criteria selected by experts.

Table 24 Analytical links to evaluation framework and experts answers

Qualitative Evaluation Criterion	Frequency (No. of Experts)	Related Evaluation Dimension	Analytical Link
Operational efficiency	8	Innovation & Value Creation	Seen as the main indicator of successful integration through automation, faster processes, and reduced costs.
Scalability and flexibility	7	Technological Depth & Maturity	Reflects technological adaptability and efficient use of cloud resources under varying operational loads.
Risk management and compliance	7	Technological Depth & Maturity	Highlights governance and regulatory reliability of AI and Cloud systems in sensitive financial operations.
Cybersecurity and data protection	6	Technological Depth & Maturity	Emphasises trust and system resilience as key aspects of sustainable deep-tech adoption.
Customer experience and trust	6	Innovation & Value Creation / Impact & Sustainability	Demonstrates AI's role in personalisation, service quality, and digital confidence.
Innovation capacity	5	Knowledge & Ecosystem / Impact & Sustainability	Reflects how banks leverage AI and Cloud for continuous innovation and long-term competitiveness.

Source: compiled by author

Eight question: What are the most pressing barriers to adopting AI and Cloud in banking?

With this question goal was to identify what barriers are being faced in order to adapt AI and Cloud. By identifying it, evaluation framework and model for AI and Cloud implementation could be enriched and adapted in order to limit these barriers.

Table 25 Key barriers to AI and Cloud adoption in banking: experts' perspectives

Key Barrier	Expert Statements	Analytical Insight
Regulatory and Data Protection Constraints	"Regulations, data protection rules, making sure AI is safe" (P1); "EU data must stay inside EU" (P2); "GDPR and local laws slow implementation" (P3).	Regulatory complexity and data sovereignty concerns remain the most cited obstacles, limiting AI model deployment and cross-border cloud use.
Legacy Systems and Technical Debt	"Biggest issue is legacy systems and old architecture" (P4); "Many tools don't integrate well" (P6).	Outdated systems hinder cloud migration and create high technical debt, slowing deep-tech transformation.

Lack of Skills and Expertise	"Lack of skilled people is a big issue – both in tech and in business understanding of AI" (P4); "Many teams do not have enough knowledge" (P5).	Human capital gaps in AI and cloud literacy limit the scale and quality of implementation.
Organisational Resistance and Culture	"Mindset and communication are main problems; business often does not understand the changes" (P6); "People are afraid to change or don't understand what AI really means for their job" (P8).	Cultural inertia, limited cross-functional understanding, and unclear ownership slow innovation adoption.
Integration Complexity	"Legacy systems make integration hard" (P5); "Unclear ownership and too many experiments with no clear outcomes" (P7).	Fragmented data structures and poor coordination increase implementation time and reduce project success.
Cost and Vendor Dependence	"Cost and vendor dependency make management hesitant to move too fast" (P4).	Concerns about financial risk and dependency on large providers discourage large-scale adoption.

Source: compiled by author

As shown in Table 24, the most recurrent barriers to AI and Cloud adoption include regulatory restrictions, outdated system infrastructure, and limited organisational readiness. Furhtermore, experts' statements illustrate that these obstacles are deeply interconnected with each other and depend on each other. For example: regulation restricts data use, legacy systems reduce integration efficiency, and a shortage of skilled professionals amplifies dependence on external providers. These findings mirror academic discussions on deep-tech adoption challenges, suggesting that overcoming such barriers requires a combination of regulatory adaptation, internal capability development, and modernisation of core banking infrastructure.

Ninth question: In your opinion, how do regulatory requirements and compliance standards shape or constrain the integration of AI and Cloud in core banking operations?

Most experts agreed with the idea of regulatory requirements being both restrictive and protectionist for banking institutions. Regulatory bodies provide the necessary oversight to protect consumers from data breaches, protect customer information and hold companies accountable. However, regulatory bodies also reduce the speed at which banks can implement new technologies by requiring lengthy approval processes, documentation and audits. This is a common dilemma in research about financial innovation where regulatory agencies ensure consumer confidence and financial system stability however they restrict the ability of companies to innovate quickly (Hon & Millard, 2018).

Table 26 Experts' perspectives on regulatory and compliance influence on AI and Cloud integration

Regulatory Impact Theme	Illustrative Expert Statements	Analytical Insight
Operational restraint and slower adoption	"It restrains banks from faster integrations" (P1); "It slows it down, makes it more complicated to implement" (P3).	Compliance requirements and approval processes delay innovation cycles and reduce agility.
Control and security assurance	"It helps to stay in line and not go overboard with new technology" (P2); "We must always think about data privacy, encryption, access rights, audit logs" (P5).	Regulation ensures responsible innovation, reinforcing trust and protecting customer assets.
Increased bureaucracy and cost	"They create a lot of control points and documentation" (P6); "Every change must be documented and approved" (P8).	Administrative requirements increase project complexity and resource demands.
Data governance and transparency challenges	"AI makes it tricky because you need to explain how decisions are made. Transparency and audit trails are still hard to achieve" (P7).	Regulatory expectations around explainability and auditability remain difficult to meet, especially for AI models.
Balanced view: protection and innovation	"It makes sure everything is up to the law and we don't risk impacting customers and their money" (P1).	While regulation slows innovation, it is recognised as essential for ensuring safety, accountability, and customer trust.

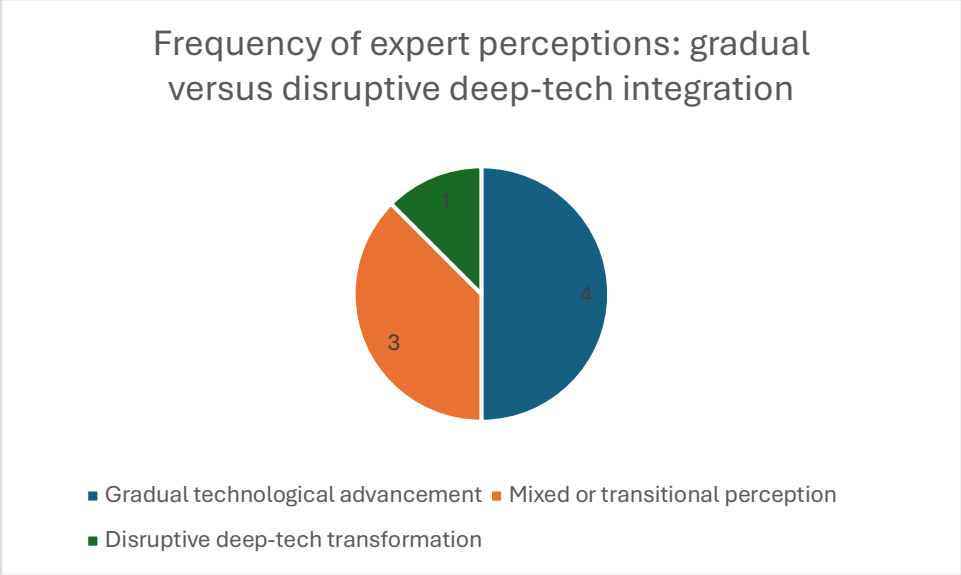
Source: compiled by author

As shown in Table 25, experts regard regulation as both a necessary protective mechanism for innovation in deep technology and a constraint that limits the development of AI and Cloud based systems. Compliance with regulatory requirements protects consumers' personal data by ensuring transparency and ethical practices, however, they also hinder the speed at which such systems can be integrated into banking environments. Therefore, future efforts to integrate technologies will rely upon how well financial institutions can reconcile their increasing need for technological flexibility with evolving compliance requirements.

Tenth question: Do you see AI and Cloud implementation in banking as a disruptive deep-tech technology or just a gradual technological advancement?

With this question the goal was to find out if AI and Cloud in banking is seen as deep-tech technology and if frameworks and theories for deep-tech implementations can be applied.

Figure 8 Frequency of expert perceptions: gradual versus disruptive deep-tech integration



Source: compiled by author

As seen in Figure 8 Most experts consider AI and Cloud adoption as steady, incremental progress shaped by regulation and legacy infrastructure. Several experts view the process as gradual now but potentially disruptive over time as systems mature and integration deepens. Finally, a small minority see current developments as already representing a deep-tech transformation in banking operations. This shows that AI and Cloud computing can be considered as deep-tech technology, however its' implementation in banking sector is still very incremental and represents gradual technological advancement.

Eleventh question: Looking ahead, what do you believe will be the most critical success factors for the Banking sector that aim to systematically integrate AI and Cloud into their core operations over the next five year?

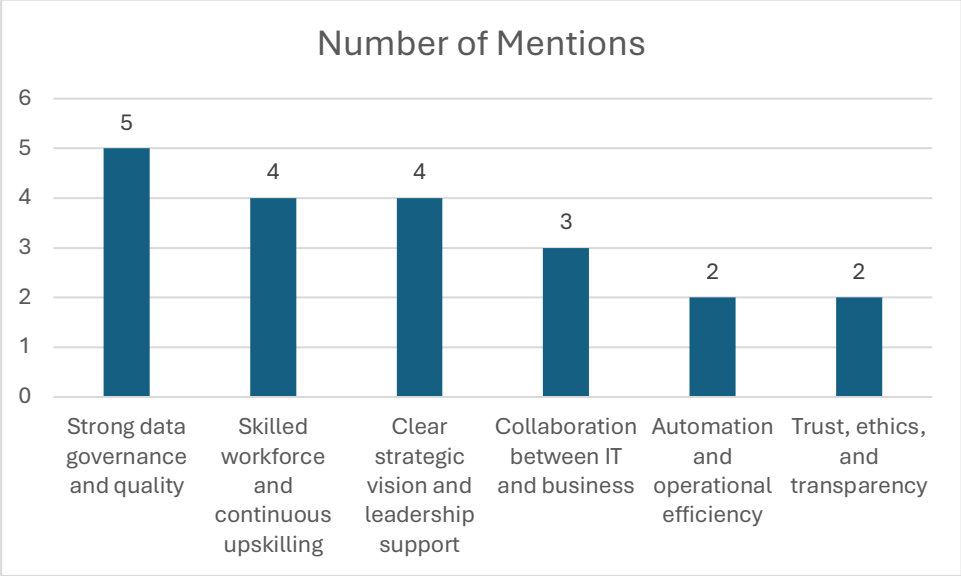
The most important success factors for systematic integration of AI and cloud technologies during the next five years will be a set of several priorities, including strategic leadership, data governance, talent development, trust, through ethics, transparency, and innovation, collaboration between business and IT and automation.

Table 27 Experts' perspectives on key success factors for AI and Cloud integration in banking

Success Factor	Expert Statements	Analytical Insight
Strong data governance and quality	"Without clean and trusted data, AI won't deliver real value." (P3)	High-quality, well-managed data is seen as the foundation of reliable and scalable AI-Cloud systems.
Clear strategic vision and leadership support	"Clear strategy and leadership support so teams know why they're doing it, not just following trends." (P3, P5)	Leadership-driven strategies ensure that AI and Cloud initiatives serve defined business purposes.
Skilled workforce and continuous upskilling	"Talent and upskilling will matter a lot, since AI and Cloud need people who understand both tech and banking." (P3, P4)	Expertise across technical and financial domains is essential to sustain digital transformation.
Collaboration between IT and business	"Good cooperation between IT and business is key." (P6)	Cross-functional collaboration aligns technology design with customer and business needs.
Automation and operational efficiency	"Fully automated customer journey and automated engineers' workflows would be a good measure." (P1)	Automation of internal and customer-facing processes signals successful integration and efficiency.
Trust, ethics, and transparency	"Building trust through transparent data use and strong security is essential." (P2)	Ethical AI practices and strong security standards are critical for long-term customer and regulatory confidence.

Source: compiled by author

Figure 9 Frequency Analysis of Success Factors



Source: compiled by author

Table 27, and Figure 9 illustrate that data quality, strategic leadership, and workforce skills were the most frequently identified as success factors, while trust and ethical governance were much less frequently cited but considered critical to enabling long term success with integrating AI and cloud computing. The research indicates that achieving technological advantages will require more than simply investing in technology; it will require creating governance maturity, interdepartmental cooperation, and innovation through ethics. Therefore, the next stage of deep tech integration within banking will be shaped by how well banks can integrate their human, organizational and technological resources into a cohesive long-term plan.

Research summary:

- Experts agreed that AI and Cloud technologies create significant value in banking by automating operations, improving accuracy, and supporting innovation.
- Combined use of AI and Cloud provides scalability, agility, and faster data-driven decision-making.
- High-quality integration is achieved through alignment of technology and business goals, ensuring reliability, security, and compliance.
- Key success criteria: operational efficiency, scalability, compliance, cybersecurity, customer experience, and innovation capacity.
- Main barriers: regulation, legacy systems, lack of skills, organisational resistance, and high costs.
- AI and Cloud adoption is gradual but demonstrates growing deep-tech characteristics.
- Successful implementation depends on leadership, governance, collaboration, and workforce competence.
- Future success will rely on strong data management, continuous learning, and ethical innovation practices.

Table 28 Summary of Research Questions and Main Findings

Research Focus	Main Findings
Assessment of AI and Cloud contribution to value creation in banking	AI and Cloud enhance efficiency, accuracy, and innovation in core financial operations.
Application of AI-Cloud integration for financial process optimisation	Combined use enables automation, scalability, and faster decision-making.
Definition of quality in AI and Cloud adoption	Quality reflects alignment between technology, business goals, and compliance standards.
Identification of key qualitative evaluation criteria	Main criteria: efficiency, scalability, compliance, cybersecurity, and innovation capacity.
Analysis of main barriers to AI and Cloud implementation	Barriers include regulation, legacy systems, lack of expertise, resistance to change, and cost.
Evaluation of AI and Cloud adoption as a deep-tech transformation	Adoption remains gradual but shows increasing deep-tech characteristics.
Determination of critical success factors for implementation	Success depends on leadership, governance, collaboration, and workforce competence.

Source: compiled by author

4. DEVELOPMENT OF AI AND CLOUD INNOVATIONS FOR CORE BANKING OPERATIONS QUALITATIVE CRITERIA APPLICATION MODEL

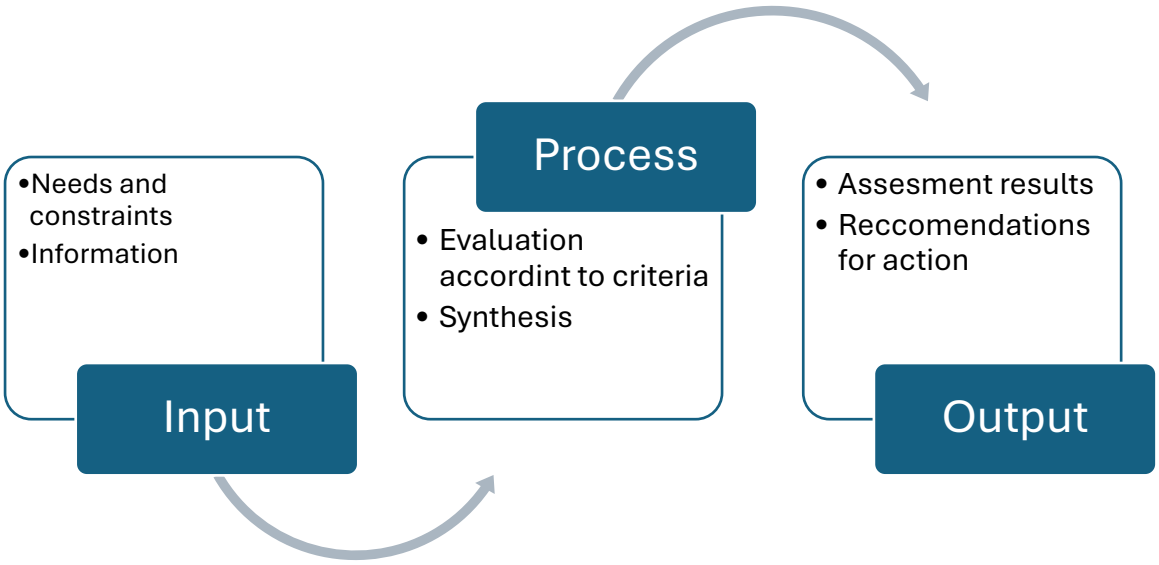
4.1 Modelling methodology

After analysing data gathered from experts' survey, qualitative criteria were proposed and approved by experts' answers. To put these finding into practise, this chapter will disucss creation of application model for Artificial intelligence and Cloud computing for optimising banking operations. Scientific literature suggests different theories for scientific modeling. Models can assume different forms - such as qualitative conceptual models, quantitative mathematical models or hybrid/mixed models - each offering distinct affordances in research design (Pilcher, 2024; Borgstede et al., 2021).

Given the complex and context-dependent nature of AI and cloud integration, this study applies a qualitative conceptual modelling approach. It allows the synthesis of expert insights and empirical findings to reveal relationships between technological, organisational and regulatory factors. As Černevičienė and Kabašinskas (2022) note, such models help to deconstruct complex systems, integrate diverse criteria and ensure transparent evaluation.

To translate the expert-based criteria into a usable model, the application model is structured as an input-process-output scheme. This structure is widely used to represent complex socio-technical systems, because it separates contextual inputs, internal transformation processes, and observable outputs in a transparent way (Galais et al., 2021). Recent work on digital transformation links digital inputs and organisational change processes with measurable benefits (Chen et al., 2025). Following this logic, the proposed model of AI and cloud innovations in core banking will start from input objects that describe the conditions and resources of the bank, represent their transformation through activities and information flows, and end with output objects that capture changes in the performance of core banking operations, as summarised in Figure 10.

Figure 10 Model summary



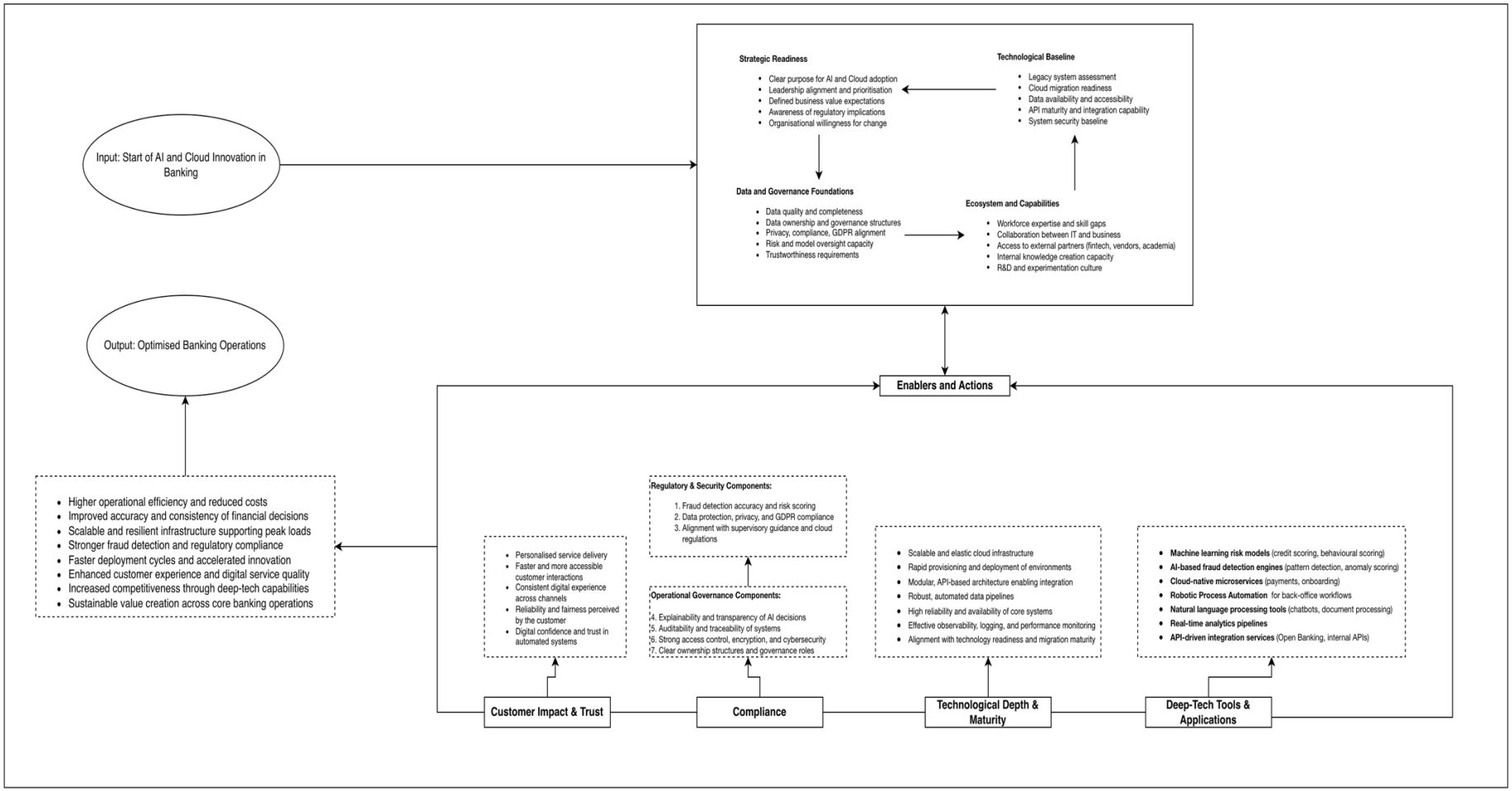
Source: compiled by author, According to: Chen et al., (2025); Černevičienė and Kabašinskas (2022)

4.2 Model analysis

A model (see Figure 10) of how to apply qualitative factors to AI and cloud in banking is a process, beginning with an Input Stage or the beginning of deep-tech innovation. During the input stage, banks evaluate their strategic readiness, technology base line, data governance, and their ability to work within an ecosystem. The evaluation of these four factors provides clarity on where the bank is at the onset, determines what barriers may exist and will outline which aspects of technology and organizational structure need to be developed prior to implementing AI and cloud technologies in a meaningful way. Upon determining the necessary steps to achieve the desired state, the model then transitions into the Actions Stage. The purpose of the actions stage is to implement specific actions that enable successful implementation of deep-tech innovations. Specific actions may include responsible use of AI, modernizing legacy systems, developing cross-functional collaboration and monitoring the effectiveness of the organization's use of AI and cloud. Once the specified actions have been implemented, the model advances to the Output Stage. The output stage involves evaluating the quality of the organizations' integration of AI and cloud using value creating criteria. Examples of value creating criteria include the level of technological advancement and maturity of the AI and cloud technology, the degree to which the AI and cloud technology is compliant with regulations, the level of customer satisfaction resulting from the use of the AI

and cloud technology and the extent to which the organizations' use of the AI and cloud technology is effective. Through the analysis of a bank's operations utilizing these criteria, a bank can identify potential gaps in its current processes, identify areas that require improvement and obtain an understanding of how far away it is from optimizing and obtaining high quality results from its use of AI and cloud. From a practical standpoint, the model serves as a tool to guide a bank in the development of a systematic approach to innovation and ensures that the resulting transformation produces long-term strategic and operational advantages for the bank.

Figure 11 Model for Bank operation optimizing with Deep-tech approach



Source: compiled by author

The proposed model provides practical means of evaluating the organizational readiness and structurally implementing AI and Cloud technologies into core banking processes. It has additional value in linking technological capabilities to other aspects of an organization (strategic, regulatory and customer oriented) which is important for the financial services industry. Successful adoption will depend on clearly aligning technology initiatives to business objectives. The input portion of the model identifies institutional and technological factors that are either supportive of limiting deep tech adoption and enables the resolution of these issues prior to widespread deployments. Once at the output stage, organizations may evaluate the level of AI and Cloud maturity by using established criteria such as; value creation, compliance, technological depth and long term sustainability. Due to continued advancement of AI and Cloud technologies, the model can be modified to include new regulatory requirements and emerging deep-tech tools. Therefore, the model does not only function as an evaluation method, it serves as a dynamic resource that may aid in strategic planning, capability development and the long term transformation of banking operations.

5. CONCLUSIONS AND RECCOMENDATIONS

Conclusions

- The literature confirms that AI and cloud computing are central to optimising core banking operations. By enabling automation, scalability, analytical accuracy, and cost efficiency, making them key drivers of banks operations modernisations, new technnology adoption.
- Expert findings show that there is a general consensus that both AI and cloud technology can be used for delivering added value in banking. Research indicated that both of these technologies add to the core financial operations through efficiency gains, improved fraud detection and compliance, as well as, enhanced scalability, and better customer service. Their combined use supports faster decisions and more integrated data management.
- Technological quality in AI and cloud integration is understood as multidimensional, autonomious, measurable performance improvements, regulatory compliance, security, organisational readiness, and alignment with business objectives.
- Six qualitative criteria define effective adoption: operational efficiency, scalability, risk and compliance management, cybersecurity and data protection, customer trust, and innovation capacity. Efficiency and scalability were identified as the most critical indicators.
- Persistent barriers include regulation, legacy infrastructure, skills shortages, organisational resistance, and vendor dependence, which collectively constrain the pace and scale of transformation.
- Experts characterise current AI and cloud adoption as incremental, with emerging deep-tech characteristics but limited by structural and regulatory constraints.
- Successful integration depends on strong data governance, strategic leadership, workforce upskilling, IT–business alignment, and transparent innovation practices.
- A structured input–process–output model was developed to guide systematic AI and cloud adoption, addressing barriers and enabling maturity assessment

Recommendations

1. Banks that plan to strengthen their technological maturity should start by systematically assessing organisational readiness, data governance, technological baselines, and employee competencies before launching large scale AI and cloud initiatives. Such preparation would help to reduce implementation risks and to align deep-tech projects with clearly defined strategic priorities.
2. Institutions are advised to focus on improving operational efficiency through automation and integrated cloud based architectures. By consolidating fragmented systems, reducing manual workloads, and accelerating the delivery of digital services, banks can achieve visible gains in areas such as compliance, fraud detection, credit risk assessment, and back office operations, where the impact of AI and cloud is particularly strong.
3. To enhance technological quality, banks should ensure that AI and cloud deployments are closely linked to business objectives and guided by transparent governance structures. Clear ownership of initiatives, well defined performance indicators, and systematic monitoring of outcomes would help to increase the reliability of deep-tech solutions and support more consistent value creation.
4. It is reasonable for banks to adopt the six identified qualitative criteria as a structured framework for evaluating AI and cloud integration. Regular assessment across these dimensions would make it possible to identify weaknesses, prioritise improvement areas, and track long term transformation progress. Special attention should be paid to operational efficiency, scalability, and compliance readiness, since these criteria were emphasised most strongly by experts.
5. To reduce the impact of barriers, banks should invest in the modernisation of legacy systems and in cloud compatible architectures, so that AI applications can be integrated more deeply and with fewer technical constraints. At the same time, institutions should strengthen internal competencies through targeted training and recruitment, particularly in roles that combine technological and financial knowledge, in order to decrease dependence on external providers.
6. Given the influence of regulatory requirements, banks should involve compliance and risk management specialists from the earliest stages of AI and

cloud projects. Jointly developed guidelines for data use, model transparency, and auditability would support responsible innovation and facilitate alignment with supervisory expectations. The integration of ethical principles into AI design and operation would further enhance trust and accountability.

7. For long term success, banks should cultivate cross functional collaboration between IT, data analytics, business units, and risk or compliance teams. Such cooperation would help to ensure that deep-tech projects address real operational needs, that solutions are usable in practice, and that technological capabilities are translated into concrete benefits for customers and internal stakeholders.
8. The proposed qualitative criteria application model should be incorporated into institutional planning and evaluation routines. Banks can use the model both at the beginning of technological transformation and when revisiting existing systems. Its structure offers a practical tool for aligning strategic objectives with technological capacity, identifying barriers, and assessing the maturity of deep-tech integration. As technologies and regulatory environments continue to evolve, the model can be updated and refined, allowing it to serve as a dynamic instrument for long term optimisation of banking operations.

Reference List

1. Alexandru Capatina, Gianita Bleoju, David Kalisz, (2024). Falling in love with strategic foresight: How deep-techcan reshape business models. Journal of Innovation & Knowledge, 9(4), 100566. https://doi.org/10.1016/j.jik.2024.100515
2. Aqmala, D., Panjaitan, R., Ardyan, E., & Putra, F. I. F. S. (2025). The role of green blue ocean strategy in enhancing frugal innovation through IoT and AI: A resource-based view perspective. Journal of Entrepreneurship, Management and Innovation, 21(2), 56–81. https://doi.org/10.7341/20252124
3. Armbrust, M., Fox, A., Griffith, R., Joseph, A. D., Katz, R., Konwinski, A., Lee, G., Patterson, D., Rabkin, A., Stoica, I., & Zaharia, M. (2010). A view of cloud computing. Communications of the ACM, 53(4), 50–58. https://doi.org/10.1145/1721654.1721672
4. Asadi, S., Abdullah, R., Safaei, M., & Jalil, R. A. (2017). Investigating the role of perceived value and perceived risk in mobile banking adoption in Malaysia. International Journal of Business Information Systems, 24(4), 433–465. https://doi.org/10.1504/IJBIS.2017.086938
5. Avram, M. G. (2014). Advantages and challenges of adopting cloud computing from an enterprise perspective. Procedia Technology, 12, 529–534. https://doi.org/10.1016/j.protcy.2013.12.525
6. Baležentis, A. & Žalimaitė, M. (2011). Ekspertinių vertinimų taikymas inovacijų plėtros veiksnių analizėje: Lietuvos inovatyvių įmonių vertinimas. *Vadybos mokslas ir studijos – kaimo verslų ir jų infrastruktūros plėtrai,* 3 (27). P. 23-31
7. Bank of America. (2024). Annual report 2024. Bank of America Corporation. https://investor.bankofamerica.com
8. Berg, T., Burg, V., Gombović, A., & Puri, M. (2020). On the rise of FinTechs: Credit scoring using digital footprints. The Review of Financial Studies, 33(7), 2845–2897. https://doi.org/10.1093/rfs/hhz099
9. Borgstede, C., Schmitt, M., & Lindenberg, S. (2021). Quantitative and qualitative approaches to generalization: A representationalist perspective. Frontiers in Psychology, 12, Article 605191. https://doi.org/10.3389/fpsyg.2021.605191
10. Buyya, R., Yeo, C. S., Venugopal, S., Broberg, J., & Brandic, I. (2009). Cloud computing and emerging IT platforms: Vision, hype, and reality for delivering computing as the 5th utility. Future Generation Computer Systems, 25(6), 599–618. https://doi.org/10.1016/j.future.2008.12.001

11. Černevičienė, J., & Kabašinskas, A. (2022). Review of multi-criteria decision making methods in finance using explainable artificial intelligence. Frontiers in Artificial Intelligence, 5, Article 827584. https://doi.org/10.3389/frai.2022.827584
12. Chen, Y., Huang, J., & Li, Y. (2025). Measuring digital transformation in high-end equipment manufacturing: An I-P-O model-based approach. Scientific Reports, 15, 27339. https://doi.org/10.1038/s41598-025-11398-9
13. Cheng, M., Qu, Y., Jiang, C., & Zhao, C. (2022). *Is cloud computing the digital solution to the future of banking? Journal of Financial Stability, 63*, 101073. https://doi.org/10.1016/j.jfs.2022.101073
14. Chethan, D., Munilakshmi, R., & Ramesh, L. (2024). *Role of artificial intelligence in banking sector: A systematic literature review*. Educational Administration: Theory and Practice, 30(1), 7459–7481. https://doi.org/10.53555/kuey.v30i1.10646
15. Chowdhary, K. R. (2020). Fundamentals of artificial intelligence. Springer. https://doi.org/10.1007/978-81-322-3972-7
16. Citigroup. (2024). Annual report 2024. Citigroup Inc. https://www.citigroup.com
17. Corbet, S., Hou, Y. H., Hu, Y., Oxley, L., & Tang, M. (2023). *Do financial innovations influence bank performance? Evidence from China*. Studies in Economics and Finance, 41(2), 241–267. https://doi.org/10.1108/SEF-02-2022-0119
18. Corrêa, N. K., Galvão, C., Santos, J., Menezes, S., Brandão, L., & Dignum, V. (2023). *Worldwide AI ethics: A review of 200 guidelines and recommendations for AI governance*. Patterns, 4(10), 100857. https://doi.org/10.1016/j.patter.2023.100857
19. Creswell, J. W., & Creswell, J. D. (2018). Research design: Qualitative, quantitative, and mixed methods approaches (5th ed.). SAGE Publications.
20. Creswell, J. W., & Poth, C. N. (2018). Qualitative inquiry & research design: Choosing among five approaches (4th ed.). SAGE Publications.
21. Danske Bank. (2024). Annual report. https://danskebank.com/-/media/danske-bank-com/file-cloud/2025/2/danske-bank---annual-report-2024.pdf
22. DeMarrais, K., Roulston, K., & Copple, M. (2024). Qualitative research design and methods: An introduction. Myers Education Press.
23. Denzin, N. K., & Lincoln, Y. S. (2000). Handbook of qualitative research (2nd ed.). Sage Publications.
24. Dionisio, E. A., Inacio Junior, E., Morini, C., & de Quadros Carvalho, R. (2023). Identifying necessary conditions to deep-tech entrepreneurship. RAUSP Management Journal, 58(2), 162–185. https://doi.org/10.1108/RAUSP-09-2022-0203
25. Douglas, L., & Christian, E. (2024). Revolutionizing industries with cloud computing, AI, and automation: A comprehensive overview. International Journal of Advanced Engineering Technologies and Innovations, 1(1), 167–187.

26. Dybek, P. (2023). *The impact of AI on digital banking*. The Review of European Affairs, 7(1), 1–12. Polish European Community Studies Association. 10.51149/ROEA.1.2023.1
27. European Banking Authority. (2021). Report on the use of machine learning in internal ratings-based models. https://www.eba.europa.eu
28. European Commission. (2021). Deep-techEurope: Building a resilient innovation ecosystem for the EU. Publications Office of the European Union. https://doi.org/10.2826/005280
29. European Commission. (2022). Deep-techfor digital transformation: Launchpad for EU competitiveness. Publications Office of the European Union. https://doi.org/10.2759/136572
30. European Institute of Innovation and Technology. (2023). *EIT deep tech definitions*. Publications Office of the European Union. https://www.eitdeeptechtalent.eu/the-initiative/
31. European Systemic Risk Board. (2021). *Annual report 2020* (ESRB Annual Report). https://www.esrb.europa.eu/pub/pdf/ar/2021/esrb.ar2020~f20842b253.en.pdf
32. Galais, C., Fernández-Martínez, J. L., Font, J., & Smith, G. (2021). Testing the input-process-output model of public participation. European Journal of Political Research, 60(4), 807–828. https://doi.org/10.1111/1475-6765.12427
33. Gartner. (2022). Market share analysis: Infrastructure as a service, worldwide, 2021. Gartner Research. https://www.gartner.com/en/documents/4004581
34. Haefner, N., Parida, V., Gassmann, O., & Wincent, J. (2023). Implementing and scaling artificial intelligence: A review, framework, and research agenda. Technological Forecasting and Social Change, 197, 122878. https://doi.org/10.1016/j.techfore.2023.122878
35. Hon, W. K., & Millard, C. (2018). Banking in the cloud – Part 1: Banking law and regulation. Computer Law & Security Review, 34(3), 494–511. https://doi.org/10.1016/j.clsr.2017.11.005
36. Hon, W. K., & Millard, C. (2018). Banking in the cloud – Part 2: Outsourcing law and regulation. Computer Law & Security Review, 34(4), 913–929. https://doi.org/10.1016/j.clsr.2017.11.006
37. HSBC Holdings plc. (2021). Annual report. https://www.hsbc.com/investors/results-and-announcements/all-reporting/annual-results-202-quick-read
38. HSBC Holdings plc. (2022). Annual report. https://www.hsbc.com/investors/results-and-announcements/all-reporting/annual-results-2022-quick-read
39. HSBC Holdings plc. (2023). Annual report. https://www.hsbc.com/investors/results-and-announcements/all-reporting/annual-results-2023-quick-read

40. HSBC Holdings plc. (2024). Annual report. https://www.hsbc.com/investors/results-and-announcements/annual-report
41. Hu, K., Li, M., Song, Z., Xu, K., Xia, Q., Sun, N., Zhou, P., & Xia, M. (2024). *A review of research on reinforcement learning algorithms for multi-agents*. Neurocomputing, 599, 128068. https://doi.org/10.1016/j.neucom.2024.128068
42. Hurson, A. R., & Wu, S. (Eds.). (2021). AI and cloud computing (Vol. 120). Academic Press. https://doi.org/10.1016/bs.adcom.2020.10.001
43. IDC. (2023). Worldwide public cloud services spending guide. International Data Corporation. https://my.idc.com/getdoc.jsp?containerId=prUS52460024
44. Itay Goldstein, Wei Jiang, G Andrew Karolyi, To FinTech and Beyond, The Review of Financial Studies, Volume 32, Issue 5, May 2019, Pages 1647–1661, https://doi.org/10.1093/rfs/hhz025
45. JPMorgan Chase & Co. (2021). Annual report. https://www.jpmorganchase.com/content/dam/jpmc/jpmorgan-chase-and-co/investor-relations/documents/annualreport-2021.pdf
46. JPMorgan Chase & Co. (2022). Annual report. https://www.jpmorganchase.com/content/dam/jpmc/jpmorgan-chase-and-co/investor-relations/documents/annualreport-2022.pdf
47. JPMorgan Chase & Co. (2023). Annual report. https://www.jpmorganchase.com/content/dam/jpmc/jpmorgan-chase-and-co/investor-relations/documents/annualreport-2023.pdf
48. JPMorgan Chase & Co. (2024). Annual report. https://www.jpmorganchase.com/content/dam/jpmc/jpmorgan-chase-and-co/investor-relations/documents/annualreport-2024.pdf
49. JPMorgan Chase & Co. (n.d.-a). Applied AI and machine learning. https://www.jpmorgan.com/technology/applied-ai-and-ml
50. Kaur, G., Sharma, M., & Kaur, P. (2020). AI enabled digital banking adoption. International Journal of Bank Marketing, 38(7), 1575 to 1598. https://doi.org/10.1108/IJBM-01-2020-0033
51. Khurana, D., Koli, A., Khatter, K. *et al.* Natural language processing: state of the art, current trends and challenges. *Multimed Tools Appl* **82**, 3713–3744 (2023). https://doi.org/10.1007/s11042-022-13428-4
52. Kim, W. C., & Mauborgne, R. (1999). Creating new market space. Harvard Business Review, 77(1), 83–93.
53. Kim, W. C., & Mauborgne, R. (2005). Blue ocean strategy: How to create uncontested market space and make the competition irrelevant. Harvard Business School Press.

54. Legapriyadharshini, N., Thirumalaikumari, T., Senbagam, K., Sarasu, R., Basha, H. A., & Malathi, P. (2024). Integration of AI and cloud-native technologies for personalized mobile banking experiences. In 2024 International Conference on Recent Innovation in Smart and Sustainable Technology (ICRISST) (pp. 1–6). https://doi.org/10.1109/ICRISST59181.2024.10921880
55. Lins, S., Schneider, S., Sunyaev, A., & Leimeister, J. M. (2021). Artificial Intelligence as a Service (AIaaS). Business & Information Systems Engineering, 63(4), 441–452. https://doi.org/10.1007/s12599-021-00708-w
56. Mancuso, I., Petruzzelli, A. M., Panniello, U., & Vaia, G. (2025). Business model innovation in the banking sector: How digital technologies transform innovation drivers and value mechanisms. Journal of Engineering and Technology Management, 75, 101858. https://doi.org/10.1016/j.jengtecman.2024.101858
57. Maple, C., Rana, O., Shumailov, I., Trovati, M., & Williams, R. (2023). The AI revolution: Opportunities and challenges for the finance sector. arXiv. https://arxiv.org/abs/2308.16538
58. Marinescu, D. C. (2017). Cloud computing: Theory and practice (2nd ed.). Morgan Kaufmann.
59. McKinsey & Company. (2021). *AI-powered fraud detection: Improving accuracy and speed*. McKinsey Global Institute.
60. Mell, P., & Grance, T. (2011). The NIST definition of cloud computing (Special Publication 800-145). National Institute of Standards and Technology. https://doi.org/10.6028/NIST.SP.800-145
61. Mirishli, S. (2024). *The role of legal frameworks in shaping ethical artificial intelligence use in corporate governance*. SSRN Electronic Journal, 1, 52–65. https://doi.org/10.2139/ssrn.5168616
62. Ndou, E., & Gumata, N. (2024). *Should the South African Reserve Bank lower the inflation target band? Insights from the GDP–inflation nexus*. Journal of Policy Modeling, **46**, 638–654. https://doi.org/10.1016/j.jpolmod.2024.02.004
63. Patton, M. Q. (2015). Qualitative research & evaluation methods: Integrating theory and practice (4th ed.). SAGE Publications.
64. Pilcher, N. (2024). Qualitative, quantitative, or mixed? Implications for research values, assumptions, and practices. Quality & Quantity. https://doi.org/10.1007/s11135-023-01734-4
65. Prinz, A., Grimmer, C., & Schurz, G. (2023). Models, systems and descriptions. Frontiers in Computer Science, 5, Article 1031807. https://doi.org/10.3389/fcomp.2023.1031807

66. Romme, A. G. L., Reip, N., & Perkmann, M. (2023). Designing a deep-tech venture builder: A case-based framework. Journal of Organization Design, 12, 74–95. https://doi.org/10.1007/s41469-023-00144-y
67. Russell, S. J., & Norvig, P. (2016). Artificial intelligence: A modern approach (3rd ed.). Pearson.
68. Shalev-Shwartz, S., & Ben-David, S. (2014). *Understanding machine learning: From theory to algorithms*. Cambridge University Press
69. Synergy Research Group. (2023). Hyperscale cloud market share update. https://www.srgresearch.com
70. Tang, C., Abbatematteo, B., Hu, J., Chandra, R., Martín-Martín, R., & Stone, P. (2025). *Deep reinforcement learning for robotics: A survey of real-world successes*. Annual Review of Control, Robotics, and Autonomous Systems, 8, 153–188. https://doi.org/10.1146/annurev-control-030323-022510
71. Vinoth, S., Vemula, H. L., Haralayya, B., Mamgain, N., Hasan, M. F., & Naved, M. (2022). Application of cloud computing in banking and e-commerce and related security threats. Materials Today: Proceedings, 51, 2172–2175. https://doi.org/10.1016/j.matpr.2021.11.121
72. Wang, Z., Chen, C., Guo, B., Yu, Z., & Zhou, X. (2016). Internet Plus in China. IT Professional, 18(3), 5–8. https://doi.org/10.1109/MITP.2016.47
73. Wells Fargo. (2024). Annual report 2024. Wells Fargo and Company. https://www.wellsfargo.com
74. Wierzbowska, A. (2025). Banking sector size and economic performance in the Euro area countries. Economic and Financial Review, 12(1), 45–67. https://doi.org/10.1007/s10663-025-09653-3
75. World Bank Group Annual Report 2025 (APA 7 reference) World Bank Group. (2025). *Annual report 2025*. The World Bank Group. https://documents.worldbank.org/en/publication/documents-reports/documentdetail/099503310092520301
76. Zhang, Y. (2022). *Financial system design for high-tech enterprise based on cloud service and artificial intelligence technology*. Mobile Information Systems, 2022, 1–10. https://doi.org/10.1155/2022/6372258
77. Zhou, M., Zhang, R., Xie, W., Qian, W., & Zhou, A. (2010). Security and privacy in cloud computing: A survey. In 2010 Sixth International Conference on Semantics, Knowledge and Grids (pp. 105–112). IEEE. https://doi.org/10.1109/SKG.2010.19