*Original Article*

# Cloud Migration Strategies for Mainframe Modernization: A Comparative Study of AWS, Azure, and GCP

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*Abstract -* *Mainframe systems have a track record of reliability, but they need help in today's fast-changing business world. These include high upkeep expenses and limited room for growth. This paper looks at three top cloud platforms—Amazon Web Services (AWS), Microsoft Azure, and Google Cloud Platform (GCP)—to update old mainframe programs. We compare them in detail, looking at what each does best. AWS has a wide range of tools to move data. Azure works well with cloud and on-site systems and fits into company setups. GCP leads in AI and machine learning. Azure is the top option for updating mainframes, offering compatibility with various cloud configurations, integration with current company infrastructure, and sophisticated data analysis driven by AI. These conclusions provide valuable information for companies transitioning mainframe systems to the cloud, enabling expansion, reduced expenses, and future-ready IT systems.*

## 1. Introduction

Mainframe systems have served as the core of industries like finance, healthcare, and government operations for years due to their dependable performance and power processing capabilities. However, in today's evolving digital age, businesses need IT infrastructures that can easily adapt and scale. Mainframes, prominent for their reliability, present a set of hurdles such as operational expenses, lack of scalability, and complexities that are not aligned with contemporary systems.

Organisations face challenges due to these constraints when aiming to stay in a competitive landscape favourably inclined towards flexible and cloud centric solutions. In the recent shift from mainframe systems to the cloud being a priority for businesses, there seems to be a gap in detailed studies comparing cloud platforms tailored for modernising mainframes. Existing research usually highlights the advantages of platforms or the general difficulties of transitioning to the cloud. However, it often overlooks how these platforms specifically tackle the intricate aspects of mainframe systems. This study aims to fill the missing research gaps by comparing three top cloud platforms. Amazon Web Services (AWS), Microsoft Azure and Google Cloud Platform (GCP). Focusing on their effectiveness in

modernising mainframe systems. The main issue tackled in this research is the challenge organisations encounter when choosing the cloud platform to migrate their outdated mainframe systems due to the different features offered by these platforms. Every platform provides tools and methods for migration; however, there is a lack of clear direction on which option best suits specific mainframe related needs. This paper assesses AWS Azure and GCP to help organisations make informed choices about cloud migration. This will empower them to address the constraints of their outdated mainframes and transition to IT environments.

## 2. Literature Review

The shift from mainframe systems to cloud-based setups has garnered significant attention in research circles due to the scalability and cost-effectiveness provided by cloud platforms. While traditional mainframe systems are known for their reliability, they come with operational expenses and do not offer the flexibility required for today's business needs. As a result, organisations are investigating approaches to move away from mainframe infrastructures and towards cloud-based options. Many research studies have delved into these shifts and technological changes by looking at cloud services such as Amazon Web Services (AWS), Microsoft Azure or Google Cloud Platform (GCP).
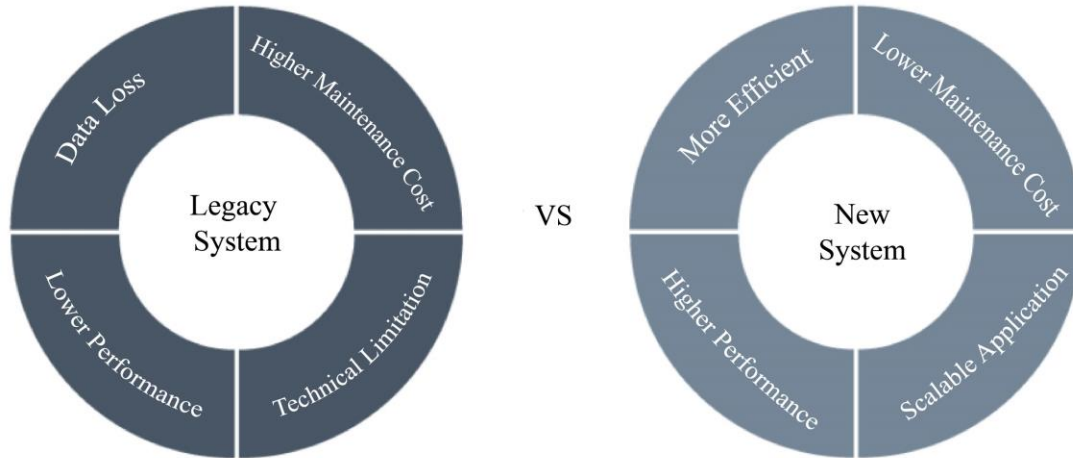
**Fig. 1 Reason for modernization of legacy systems**

There is a noticeable gap in the current literature regarding thoroughly comparing how these platforms tackle the challenges of updating mainframe systems. Despite the benefits of transitioning to the cloud environment, organisations encounter various obstacles during the transformation of mainframe systems that may add complexity to the endeavor. Migrating volumes of data from mainframes to the cloud can be a complex task due to the close integration with older applications on these systems and the need to maintain data integrity and consistency throughout the process. The transition necessitates Extract Transform Load (ETL) processes that come with the challenge of potential data loss or corruption. Traditional software programs written in languages like COBOL might not work well with cloud systems. They might need to be updated to fit seamlessly with the latest technology trends and frameworks. Mainframes play a role in organisations' IT setups, and shifting them necessitates a meticulous approach to handling interconnections with other systems, such as ERP and databases, to prevent any disturbances. Mainframe systems frequently deal with information that can pose security and compliance hurdles when transferring to the cloud environment due to the need for enhanced encryption protocols and adherence to regulatory standards for identity management. The upfront costs for transitioning to a system can be quite substantial due to expenses related to updating software and training employees while efficiently overseeing a mix of old and new technologies, which is crucial for companies to handle effectively. Mainframe specialists might lack the required expertise to handle native settings effectively, leading to a demand for additional training and re-skilling. This poses another obstacle amidst the endeavor to modernise. Previous studies have pointed out the strengths of AWS in providing a range of migration tools like AWS Migration Hub for hybrid environments and AWS Snowball for large-scale data transfer support. The findings highlight how AWS can help reduce expenses while improving system availability and flexibility for organisations with intricate IT needs. However, research often fails to address the complexities of handling integrated legacy systems within AWS, which may present hurdles during migration. Research into Azure highlights the platform's strong hybrid cloud features with Azure Arc, and its smooth incorporation into business systems is also emphasised. Furthermore, Azure offers AI and machine learning services such as Azure Cognitive Services, which are important facilitators for businesses seeking to update their IT infrastructures and integrate AI-driven analytics into their operations. While Azure has its strengths, previous studies concentrate on its enterprise connections without examining how its tools stack up against other platforms for modernising mainframes. However, Google Cloud Platform (GCP) is often praised for its strong artificial intelligence and data analysis features like BigQuery and TensorFlow. Nonetheless, critics note that GCP may not provide all the tools needed to migrate mainframe systems effectively. Organisations with established legacy systems might find GCP less suitable in this regard. While the platform excels in the opinion of AI-powered cloud applications, its effectiveness in modernising mainframe systems has not been extensively studied.

### 2.1. Novelty of the Research

This research addresses a gap in what we know by comparing AWS, Azure and GCP in the context of modernising mainframes side by side. A departure from studies that mainly concentrate on platforms, this study meticulously assesses these platforms using five essential criteria: tools for migrating mainframes, scalability, support for hybrid cloud environments, AI features and cost-effectiveness. The uniqueness of this project is seen in its emphasis on the hurdles faced in updating mainframes today, like transferring entrenched outdated systems and incorporating AI-based analytics into modern cloud settings. The paper presents perspectives by pointing out the differences in how each platform handles hybrid cloud integration and optimises AI and Machine Learning (ML).

However, AWS and Azure are known for their cloud setups. As per this research, Azure Arc and AWS's Outposts are scrutinised in detail to see how they assist in transitioning from mainframes to the cloud step by step. In addition, this study explores GCP's strengths in AI and analytics for organisations that prioritise data processing and AI capabilities but raises concerns about its compatibility with core legacy migrations due to a shortage of mainframe tools. Examining the three cloud services through examples and technical materials in this document can help companies better choose the ideal cloud platform for updating their mainframe infrastructures. The study results offer insights by assessing AWS Azure` and GCP, empowering leaders with essential information to modernise mainframes effectively.



**Fig. 2 AWS Vs Azure Vs GCP**

## 3. Methodology

The selection of AWS, Azure, and GCP was made in these research projects because of their very strong presence in the marketplace, a wide array of service options, and known excellence in cloud solution provisioning for large enterprise customers. The highlighted platforms are the most flexible and scalable and can support older systems efficiently. Due to these attributes, they will fit the requirements for the renewal of mainframe technology.

### 3.1. Selection of Cloud Platforms

The study focused on AWS, Azure, and GCP, which are recognised as the industry's leading and most dependable cloud platforms. Each of these brings different benefits and abilities when transitioning to the cloud for systems.

Companies rate them highly for their vital infrastructure, scalability, and flexibility, making them favorable options for modernising legacy systems such as mainframes. Furthermore, each platform provides specialised tools for cloud migration and system updates, enabling a comprehensive comparative analysis.

### 3.2. Comparison Criteria

When comparing cloud platforms, we evaluated them based on several critical criteria:

### 3.2.1. Mainframe Migration Tools

This criterion assesses each platform's toolset and capabilities for mainframe modernisation, including the support for application refactoring, re-platforming, and hybrid architectures. The tools evaluated included AWS Migration Hub, Azure Migrate, and GCP's Kubernetes Engine, among others.

### 3.2.2. Scalability and Flexibility

Scalability is key in modernising mainframes, which must handle varying workloads. This criterion evaluates each platform's ability to scale resources on demand and its flexibility in meeting the evolving needs of enterprise applications.

### 3.2.3. Hybrid Cloud Support

Many organisations prefer a phased migration strategy, keeping some workloads on-premises while moving others to the cloud. This criterion evaluates how each platform supports hybrid cloud environments, allowing incremental migration of mainframe workloads while maintaining on-premises systems.

### 3.2.4. AI and Analytics Capabilities

Given the increasing importance of AI and data analytics in modern IT infrastructure, this criterion assesses how each platform integrates AI and Machine Learning (ML) tools. It includes support for predictive analytics, AI-driven optimisations, and advanced data processing through tools like AWS SageMaker, Azure Cognitive Services, and GCP's BigQuery.

### 3.2.5. Cost Efficiency

This criterion examines the total cost of ownership, including initial migration costs, ongoing operational costs, and any long-term expenses. Public pricing models and case studies were used to evaluate how cost-effective each platform is for mainframe modernisation.

### 3.3. Evaluation Process

The review thoroughly assesses various cloud platforms for mainframe modernisation projects, examining technical

documentation, case studies, and real-world implementations. The collected data evaluates tool support during migration, scalability, AI capabilities, and cost comparisons based on public pricing models and migration case studies.

### 3.4. Metrics for Success

In the present study, success will be defined by the platform's capability to offer seamless migration tools, cost-effective solutions, and enhanced system performance post-migration. This review also evaluates the platforms' support for hybrid cloud architectures and AI-driven modernisation features.

This analysis comprehensively assesses AWS, Azure, and GCP's strengths and challenges to recommend the most suitable platform for mainframe modernisation. The diagram (see Figure 3) shows the key phases of mainframe modernisation. These phases involve moving data from a legacy mainframe system to the cloud through re-platforming or refactoring. After that, hybrid cloud environments with AI/ML capabilities are integrated.

## 4. Case Studies in Mainframe Modernization

### 4.1. Case Study 1: AWS and Financial Institution Modernization

One of the largest financial institutions in North America faced significant challenges with its legacy mainframe systems. These systems supported critical banking functions but were becoming increasingly costly to maintain and difficult to scale. The institution embarked on a modernisation journey using Amazon Web Services (AWS), leveraging tools like the AWS Mainframe Modernization platform, AWS Snowball for large-scale data transfers, and AWS Migration Hub for hybrid environments.

#### 4.1.1. Key Challenges and Solutions
- Data Migration Complexity: The institution used AWS Snowball to move terabytes of financial data securely and efficiently, addressing the challenges associated with transferring large amounts of sensitive data.
- Application Refactoring: The bank leveraged AWS's automated refactoring tools to convert COBOL applications into Java microservices, enabling a smoother transition to a cloud-native architecture.
- Outcome: After the migration, the institution saw a 40% reduction in operational costs and increased system scalability, allowing it to handle peak banking loads more efficiently.

### 4.2. Case Study 2: Azure in Healthcare Mainframe Modernization

A leading healthcare provider in Europe needed to modernise its ageing mainframe systems to improve patient data management and integrate AI-driven analytics. The organisation chose Microsoft Azure for its hybrid solid cloud capabilities and integration with existing enterprise systems.
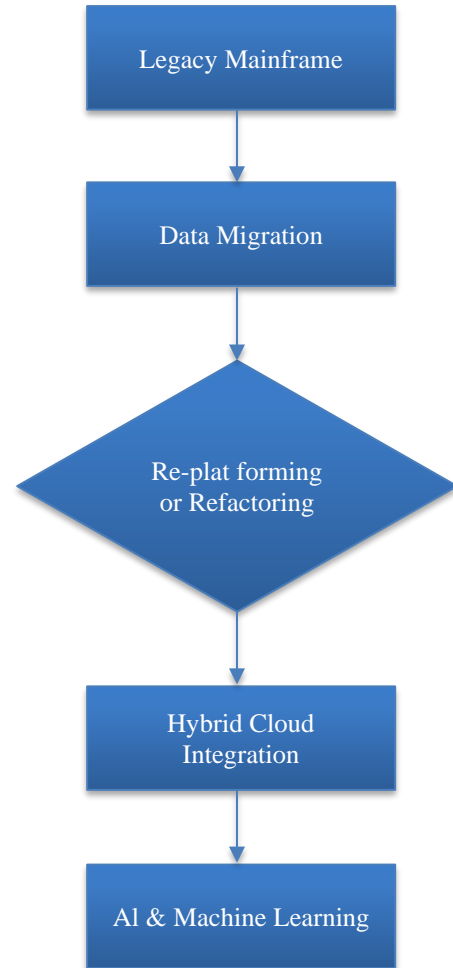


**Fig. 3 Mainframe modernization process flow**

#### 4.2.1. Key Challenges and Solutions
- Hybrid Cloud Integration: The provider used Azure Arc to maintain some workloads on-premises while shifting non-critical patient management functions to the cloud, ensuring compliance with strict healthcare regulations.
- AI and Analytics: Azure Cognitive Services and Machine Learning were employed to analyse patient data, providing valuable insights into treatment effectiveness and patient outcomes.
- Outcome: The healthcare provider experienced a 30% improvement in operational efficiency, faster data access times, and the ability to provide AI-powered patient care recommendations.

### 4.3. Case Study 3: GCP and AI-Driven Modernization for Retail

A global retail company with a complex legacy mainframe system turned to Google Cloud Platform (GCP) to modernise its inventory management and customer service applications. GCP's focus on AI and machine learning made it ideal for the company's data-heavy, analytics-driven operations.

### 4.3.1. Key Challenges and Solutions

- Application Containerisation: The company used GCP's Kubernetes Engine to containerise its monolithic mainframe applications, allowing it to break down legacy systems into manageable microservices.
- AI Integration: The retailer developed predictive models for inventory management with TensorFlow and BigQuery, which led to more accurate stock replenishment and reduced costs.
- Outcome: The company achieved a 25% reduction in inventory costs and improved customer satisfaction through faster response times powered by AI-driven analytics.

## 5. Results and Analysis

The overview of AWS, Azure, and GCP to mainframe modernisation was beneficial in understanding their respective functionalities, limitations, and applicability for migrating legacy systems onto cloud-based environments. This section covers the performance rating of each platform regarding the predefined criteria within the methodology, including their respective migration tools, scalability, support for hybrid clouds, AI and analytics capabilities, and their cost-effectiveness.

### 5.1. Mainframe Migration Tools

AWS, Azure, and GCP provide various tools for modernising mainframes, with each platform excelling in different aspects. AWS is notable for its Mainframe Modernization Platform, which supports refactoring and re-platforming strategies. AWS Migration Hub and AWS Snowball offer solid solutions for transferring large datasets and simplifying complex migration processes. AWS's flexibility allows businesses to select between complete migration to the cloud or hybrid architectures, making it an appealing option for organisations with diverse migration needs. However, AWS's extensive service offerings can bring complexity, particularly for organisations with highly integrated mainframe systems.

Azure provides robust tools for migrating from mainframes to the cloud, with particular strength in transitioning from COBOL to .NET. Its comprehensive range of migration services, which includes Azure Migrate and Azure Logic Apps, facilitates seamless integration with existing enterprise systems. Azure's close alignment with Microsoft technologies such as Active Directory and Power BI simplifies modernising mainframe environments for enterprises already utilising Microsoft products.[3],[4] Although less concentrated on mainframe-specific tools than AWS and Azure, GCP utilises its containerisation and microservices expertise. GCP's Kubernetes Engine (GKE) is highly effective in containerising traditional applications, enabling efficient modernisation by restructuring monolithic mainframe systems into cloud-native microservices.

Nevertheless, GCP needs more specialised tools for mainframe migration, making it a less favorable option for organisations with deeply integrated legacy systems.[6]

### 5.2. Scalability and Flexibility

All three platforms demonstrate robust scalability, allowing enterprises to allocate resources as needed dynamically. AWS offers the largest set of scalable services that allow scaling up or scaling down infrastructure according to demand. Its ability to perform large-scale transactions makes it popular among big enterprises with high transaction volumes. Azure Arc extends on-premises infrastructure into the cloud, building an environment consistent and extensible for the legacy system to coexist with modern cloud-native applications. Azure's fantastic scalability is coupled with this, particularly in the hybrid cloud. GCP's scalability is robust and driven by advanced serverless infrastructure such as Google Cloud Functions and the App Engine. These services support auto-scaling based on workload, and GCP, therefore, becomes very flexible for organisations that have to respond quickly to varied demands.

### 5.3. Hybrid Cloud Support

Hybrid cloud capabilities are vital for businesses seeking to maintain certain operations on-premises while transitioning other workloads to the cloud. Azure stands out in this domain, offering a robust hybrid cloud framework, mainly through its Azure Arc feature. This capability empowers enterprises to effectively oversee and modernise mainframe systems while upholding crucial on-premises operations, facilitating a seamless, gradual shift to the cloud. AWS supports hybrid architectures but is more focused on complete cloud migration. AWS's hybrid cloud solutions, such as AWS Outposts, offer some flexibility for organisations needing to retain on-premises infrastructure. However, they are not as seamless as Azure's offerings.[7] Anthos from GCP supports hybrid cloud, enabling organisations to oversee workloads across various environments. Nevertheless, compared to Azure, GCP's hybrid cloud features are less developed, positioning it as a secondary choice for enterprises with intricate legacy systems needing comprehensive hybrid support.

### 5.4. AI and Analytics Capabilities

In AI and machine learning, GCP boasts one of the most advanced suites of tools: BigQuery, TensorFlow, and AI Platform.[5],[7] These services enable organisations to adopt next-generation analytics in their renewed infrastructures with unrivalled real-time insight and predictive analytics. Thus, GCP becomes the best fit for organisations whose operations revolve entirely around AI-driven applications.[11] Azure also provides rich AI capabilities with Azure Cognitive Services and Machine Learning, allowing enterprises to build deep analytics into their modernised applications.[3] AWS also has several AI-related services. These include Amazon SageMaker and AWS Lambda. The former pair allows

organisations to machine-learn and apply predictive analytics on their mainframe data. However, AWS's roster of AI-related services is less integrated than those available on GCP.[1]

### 5.5. Cost Efficiency

Azure is the most cost-effective option for an organisation willing to modernise its mainframe systems with continuity of operations. Azure's support for hybrid clouds reduces the requirement for full re-platforming, decreasing initial migration and operational running costs.

AWS provides all comprehensive toolsets but often becomes more expensive in the long term due to proprietary services building more potential risks of lock-in to a vendor.

Despite its strong AI capabilities, GCP may be less cost-effective for mainframe modernisation due to its limited focus on this specific migration path.[4] The cost efficiency of mainframe modernisation was analysed over five years for the three leading cloud platforms: AWS, Azure, and GCP. Azure consistently declines operational costs, providing the most cost-effective solution over time (see Figure 4). AWS starts with the highest initial cost and maintains a relatively higher operational expense throughout the period, while GCP shows moderate cost reductions. This summary (see Table 1) outlines each platform's main features and performance based on specific criteria outlined in a paper. The criteria include mainframe migration tools, scalability, hybrid cloud support, AI capabilities, and cost efficiency.
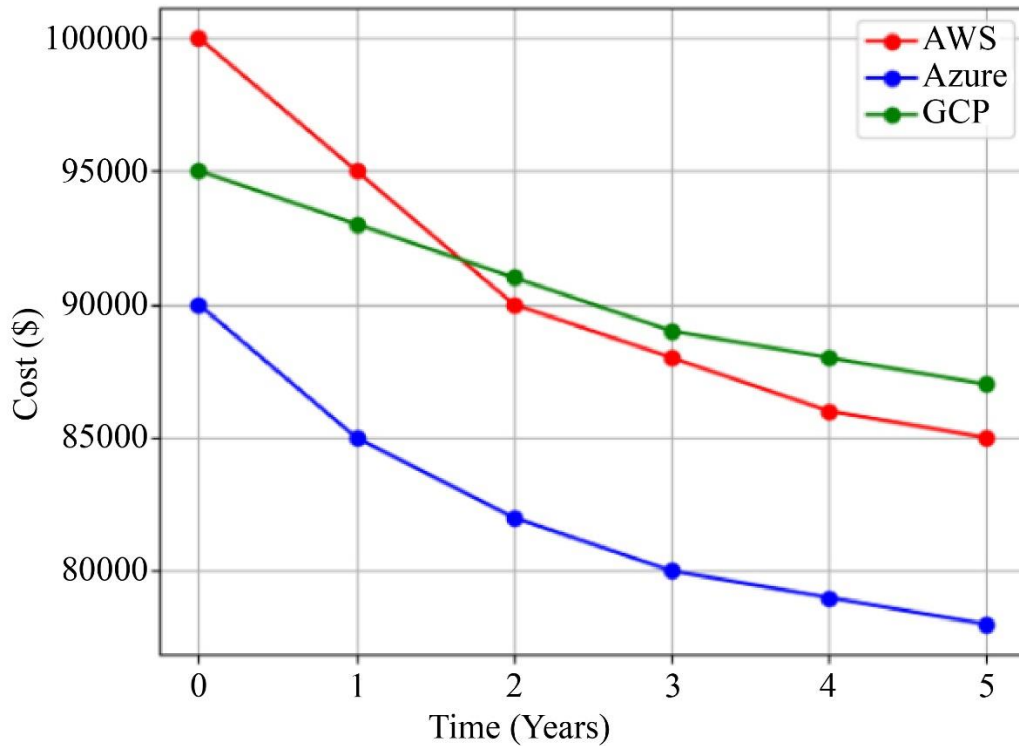


**Fig. 4 Cost efficiency of mainframe modernisation on AWS, Azure, and GCP over time**

**Table 1. Performance Comparison of AWS, Azure, and GCP for Mainframe Modernization**

| Criteria | AWS | Azure | GCP |
|---|---|---|---|
| **Mainframe Migration Tools** | AWS Migration Hub, AWS Snowball, Mainframe Modernization Platform | Azure Migrate, Logic Apps, COBOL-to-.NET transitions | Kubernetes Engine, Anthos for containerisation and microservices |
| **Scalability** | High scalability with EC2, RDS | Exceptional scalability via Azure Arc for hybrid environments | Advanced serverless scaling with Cloud Functions, App Engine |
| **Hybrid Cloud Support** | AWS Outposts for Hybrid Cloud | Robust hybrid cloud support through Azure Arc | Anthos for multi-cloud hybrid workloads |
| **AI and Analytics** | Amazon SageMaker, AWS Lambda | Azure Cognitive Services, Azure Machine Learning | BigQuery, TensorFlow, AI Platform |
| **Cost Efficiency** | Higher initial and operational costs | Cost-effective, especially for hybrid environments | Moderate cost, lower focus on mainframe tools |

### 5.6. Expanded Scope: Including IBM Cloud and Oracle Cloud for Mainframe Modernization

*5.6.1. IBM Cloud for Mainframe Modernization*

IBM Cloud is an aspect to consider in this analysis as IBM has a lot of expertise in mainframe systems with its IBM Z series products. IBM Cloud provides solutions like IBM Z Hybrid Cloud, enabling businesses to expand their current on-premises mainframe setup to the cloud. This hybrid method benefits companies needing a transition plan by keeping critical operations on traditional mainframes while moving other tasks to the cloud environment. IBM Cloud also offers features in quantum computing. It integrates AI and blockchain technologies that could benefit companies seeking to update their mainframe systems with the latest technology advancements. Moreover, the IBM DevOps toolchain for Z systems allows businesses to modernise COOL applications more efficiently.

*Strengths*
- Deep integration with IBM Z mainframe systems
- Robust hybrid cloud support with IBM Z Hybrid Cloud
- Specialised tools for mainframe DevOps and COBOL modernisation
- Advanced AI and quantum computing capabilities for future-proofing IT infrastructures

*Weaknesses*
- It may not be as flexible as AWS or Azure for organisations using non-IBM mainframes.
- Higher initial setup costs compared to other cloud platforms

*5.6.2. Oracle Cloud for Mainframe Modernization*

Oracle Cloud has become a contender in the field, especially for businesses that heavily depend on databases and Enterprise Resource Planning (ERP) systems. The robust database management capabilities of Oracle and its Autonomous Database service make it a top pick for updating data mainframes. Organisations already utilising Oracle's mainframe solutions find a transition with Oracle Clouds compatibility with legacy Oracle systems. Moreover, Oracle Cloud provides solutions for transferring mainframe programs to a container-based framework, allowing businesses to divide mainframe applications into smaller microservices. Oracle emphasis is on High-Performance Computing (HPC). AI-driven data analytics positions it as a reliable option for companies looking to harness sophisticated technologies while updating their older systems.

*Strengths*
- Strong integration with legacy Oracle mainframes and databases
- Advanced AI and analytics capabilities for data-driven modernisation
- Supports containerisation of mainframe applications for a more modular architecture

- Cost-effective for organisations with pre-existing Oracle infrastructure

*Weaknesses*
- Limited hybrid cloud capabilities compared to Azure and IBM Cloud
- Smaller ecosystem of third-party tools compared to AWS and GCP

*5.6.3. Comparative Analysis Summary*

This report presents a comprehensive overview of the mainframe modernisation choices by considering both IBM Cloud and Oracle Cloud. The following key insights have been noted: AWS is still a choice because of its wide range of tools for upgrading and modernising mainframe applications and its various migration alternatives; however, costs could go up for companies with complex mainframe setups that are deeply connected. Azure is known for its hybrid cloud features and seamless integration with corporate systems through Azure Arc. It is an option for businesses with intricate IT setups that need to shift to the cloud gradually. Google Cloud Platform (GCP) stands out in the field of intelligence and machine learning, making it a great choice for companies that prioritise cutting-edge analytical capabilities. Nevertheless, it falls short when offering tailored solutions for transitioning from mainframe systems, which may deter enterprises with historical setups. Organisations that operate IBM Z mainframes are advised to consider IBM Cloud because of its integration with traditional IBM systems and its ability to support hybrid cloud environments. It effectively provides specialised resources for updating COBOL and facilitating DevOps practices. Oracle Cloud is a choice for businesses that heavily depend on databases and aim to update their mainframe systems using containerised microservices technology thanks to its strong database management capabilities and AI-driven analytics features that are quite attractive. This paper improves its analysis by incorporating newer cloud platforms like IBM Cloud and Oracle Cloud to cater to enterprises specific mainframe modernisation requirements more effectively and offering a wider range of solutions for decision makers to consider in modernising their legacy mainframes.

## 6. Challenges

Modernising mainframe systems, mainly through cloud migration, poses several challenges organisations must confront for a successful transition. A key challenge involves migrating data from legacy mainframe systems to modern cloud platforms. This intricate process necessitates seamless ETL (Extract, Transform, Load) operations to maintain data integrity while transferring substantial datasets across diverse architectures. The potential for data loss or corruption during this process is a notable concern.[10] One significant challenge is the compatibility between mainframe systems and modern cloud platforms such as AWS, Azure, and GCP. Mainframe applications are frequently tightly integrated with

other legacy systems, which makes complete transition challenging without substantial re-platforming or refactoring. Organisations also need to consider legacy system dependencies, as any disruption during the migration process could result in downtime or operational inefficiencies.[9] In addition, training AI models to improve mainframe functions, such as predictive maintenance or query optimisation, requires clean and structured data. However, legacy systems may not readily provide such data. Furthermore, the computational resources needed for these AI-driven operations increase implementation costs, further complicating the process.[15] Finally, cloud migration increases cybersecurity risks, necessitating strong security measures to protect sensitive data.[12] Ensuring compliance with industry standards and guarding against data breaches is essential to maintain operational security during and after the migration process.

## 7. Future Focus

In the realm of mainframe modernisation, future endeavors should prioritise refining cloud integration processes to facilitate seamless transitions from legacy systems to prominent cloud platforms such as AWS, Azure, and GCP. Improving the compatibility between current infrastructure and cloud environments is essential for minimising operational disruptions during migration. Furthermore, advancing AI and machine learning algorithms will play a pivotal role in enhancing the precision and efficiency of predictive analytics, particularly in areas such as predictive maintenance and query optimisation.[14] The focus must also shift toward cybersecurity protocols because, with increased utilisation of cloud-based systems, the chance for data breaches will be much higher. Strengthening such security measures is the key to securing sensitive data and maintaining compliance with industry regulations. Lastly, automation around data migration and system upgrades will also be critical, simplifying modernisation by minimising human interventions and making migrations seamless.[13] This way, the mainframe systems will be relevant and competitive in this fast-evolving digital world.

## 8. Conclusion

Modernising mainframes through cloud migration and AI integration enables better scaling, cost reduction, and future-proofing of IT infrastructures for organisations. This paper has identified key strengths in AWS, Azure, and GCP regarding the support of mainframe migration. Azure is arguably the most complete enterprise offering since its hybrid cloud is potent, enabling seamless integration, and ideally suited for complex modernisation projects. AWS has a suite of tools to refactor and re-platform, offering a myriad of flexibility toward many migration strategies. Strongest in areas related to AI and machine learning, GCP can be the best fit for those organisations that rely heavily on advanced analytics. While various benefits have been identified, organisations must address data migration complexity, compatibility, and cybersecurity issues for a seamless transition. Migration processes must be more comprehensively automated, AI models further developed, and security protocols bolstered. Addressing these challenges on the front end will enable organisations to realise the full advantages of cloud-based infrastructures and ensure their operational efficiency and agility will be sustained.

## References

[1] AWS Mainframe Modernization, Amazon, 2024. [Online]. Available: https://aws.amazon.com/mainframe-modernization/

[2] AWS Mainframe Migration Hub, Amazon. 2024. [Online]. Available: https://aws.amazon.com/migration-hub/

[3] Azure Arc Hybrid and Multi-cloud Solutions, Microsoft, 2023. [Online]. Available: https://azure.microsoft.com/en-us/products/azure-arc/

[4] Azure Migrate Simplify Your Migration, Microsoft, 2024. [Online]. Available: https://azure.microsoft.com/en-us/products/azure-migrate/

[5] Google Cloud, From data warehouse to a unified, AI-ready data platform, BigQuery, 2024. [Online]. Available: https://cloud.google.com/bigquery/

[6] Google Cloud, The Most Scalable and Fully Automated Kubernetes Service, Google Kubernetes Engine (GKE), 2024. [Online]. Available: https://cloud.google.com/kubernetes-engine/

[7] Google Cloud Platform AI Platform: Cloud AI and Machine Learning Products, 2024. [Online]. Available: https://cloud.google.com/products/ai

[8] Skyla Loomis et al., *Accelerate Mainframe Application Modernization With Hybrid Cloud*, IBM Redbooks, pp. 1-64, 2023. [Publisher Link]

[9] Hillery Hunter, Skyla Loomis, and Surya Duggirala, Mainframe Application Modernization with IBM Cloud and IBM zSystems, IBM Blog, 2023. [Online]. Available: https://www.ibm.com/blog/mainframe-application-modernization-with-ibm-cloud-and-ibm-zsystems/

[10] Aparna Sharma, New Study Reveals Why Mainframe Application Modernization is Key to Accelerating Digital Transformation, IBM Blog, 2023. [Online]. Available: https://www.ibm.com/blog/new-study-reveals-why-mainframe-application-modernization-is-key-to-accelerating-digital-transformation/

[11] Marlin Metzger, The Power of a Mainframe Modernization and Cloud Migration Strategy, Deloitte. [Online]. Available: https://www2.deloitte.com/us/en/pages/consulting/articles/mainframe-modernization-through-cloud-migration-strategy.html

[12] David Morley, Why Mainframe Migration is More Than Technology Transformation, Google Cloud Blog, 2024. [Online]. Available: https://cloud.google.com/blog/products/infrastructure-modernization/why-mainframe-migration-is-more-than-technology-transformation/

[13] Aman Gupta, A Data-first Approach to Mainframe Modernization, Google Cloud Blog, 2021. [Online]. Available: https://cloud.google.com/blog/products/application-modernization/a-data-first-approach-to-mainframe-modernization

[14] Mainframe Application Modernization Solutions, IBM Corporation, 2022. [Online]. Available: https://www.ibm.com/mainframe-application-modernization

[15] Mainframe Modernization Solutions, Google Cloud. [Online]. Available: https://cloud.google.com/solutions/mainframe-modernization