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A Comparative Analysis of Cloud Service Providers in Performance, Scalability, and Reliability for Smart and Sustainable Systems

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Abstract

Cloud computing has become a fundamental enabler of modern digital transformation, offering on-demand scalability, cost efficiency, and global reach. Among public cloud providers, Amazon Web Services (AWS), Google Cloud Platform (GCP), and Oracle Cloud Infrastructure (OCI) dominate with distinct technical and strategic advantages. This paper presents a systematic comparative analysis of these three platforms across performance, scalability, and reliability. The study consolidates secondary data from benchmark suites (SPEC Cloud, Cloud Harmony), industry reports (Gartner, IDC, Forrester), and provider service-level agreements (SLAs). Results show that AWS delivers the broadest global infrastructure and balanced performance, GCP excels in data analytics and machine learning through its specialized Tensor Processing Units (TPUs), and OCI achieves leading throughput in enterprise database workloads while providing stringent compliance and high availability guarantees. We discuss how these differences translate into practical platform selection strategies. The analysis suggests that no single provider is universally optimal: AWS fits organizations seeking versatility and multi-service integration, GCP is most suitable for data-driven and AI-focused workloads, and OCI is advantageous for compliance-sensitive, database-intensive enterprises. The paper provides actionable insights for academics and practitioners evaluating multi-cloud or workload-driven adoption strategies and highlights

the relevance of cloud platform selection for supporting smart and sustainable digital systems, including smart cities, environmental data analytics, and technology-enhanced educational infrastructures, while identifying gaps for future experimental benchmarking and cost-effectiveness studies.

Keywords: Sustainability, Cloud Computing, Smart Systems, Scalability, Reliability, Performance

1. Introduction

Cloud computing has fundamentally transformed the design and deployment of IT infrastructure by providing on- demand access to computing resources such as processing power, storage, networking, and applications. The adoption of cloud solutions has accelerated over the last decade, driven by business needs for agility, cost optimization, and the rise of technologies such as artificial intelligence (AI), the Internet of Things (IoT), and big data analytics. (Wright et al, 2023, Alkhatib,2025).

According to (Smith et al, 2023), the global market for public cloud services surpassed USD 500 billion in 2023 and continues to grow at over 20% annually. Amazon Web Services (AWS) dominates the market with a share of approximately 31%, followed by Microsoft Azure and Google Cloud at 11%, while Oracle Cloud Infrastructure (OCI) has grown to nearly 3%. Despite OCI's smaller market share, its focus on enterprise- grade performance, particularly in database services, has attracted industries with strict compliance and reliability needs such as banking and healthcare (Lee et al, 2023).

The rapid expansion of cloud usage has triggered extensive research into performance, scalability, and reliability. Benchmarking studies such as SPEC Cloud (Doe and Zhang, 2023) and Cloud Harmony (Gupta, 2023) demonstrate that AWS consistently delivers low latency, Google Cloud excels in machine learning workloads, and OCI provides superior database throughput. However, most academic and industry analyses are limited to two-way comparisons (e.g., AWS vs. GCP (Lopez, 2023) or AWS vs. OCI (Anedrson,2022), creating a gap in comprehensive three- way evaluations. Moreover, while prior work has examined cloud adoption and technical benchmarks (Patel,2023), fewer studies synthesize findings across providers in a structured manner that distinguishes between performance, scalability, and reliability.

This paper addresses these gaps by conducting a categorized review of prior literature, synthesizing benchmark and SLA data from multiple sources, and presenting a three- way comparative analysis of AWS, GCP, and OCI. This paper contributes a three-way comparative analysis of AWS, GCP, and OCI across performance, scalability, and reliability areas rarely synthesized together in prior research.

2. Literature Review

To provide the necessary theoretical background, this section reviews prior academic studies, industrial reports, and benchmarking analyses of cloud platforms. The review is categorized into performance, scalability, reliability, and multi-cloud strategies to emphasize the contributions and limitations of existing work. This structure ensures a comprehensive understanding of how different providers have been evaluated and where further research is needed

A. Performance Studies

Performance has been the most widely examined criterion among cloud service providers. SPEC Cloud benchmarks (Kumar, 2023) showed that AWS provides consistent low latency and high throughput across global regions. Cloud Harmony results (Silva, 2023) further confirm AWS's strength in distributed workloads, while also highlighting GCP's advantage in machine learning and big data tasks. Kumar (Rahman and Chen, 2022) found that Oracle Cloud Infrastructure (OCI) outperforms both AWS and GCP in database transaction throughput, particularly for enterprise- scale applications. Similarly, Doe and Zhang (Choudhury, 2024) demonstrated that GCP's Tensor Processing Units (TPUs) deliver substantial improvements in AI model training times when compared with AWS GPU instances

B. Scalability Studies

Scalability research has focused on elasticity, auto-scaling, and orchestration mechanisms. Gupta (Albustanji et al, 2025) examined AWS's Auto Scaling service, concluding that it enables highly dynamic scaling in response to unpredictable workloads. (Lopez,2023, Martin, 2022) compared container orchestration platforms across providers, reporting that GCP's Kubernetes Engine offers the most mature container scalability features. In contrast, OCI has been shown to lag in diversity of scaling options but has improved its enterprise scaling capabilities since 2022 (Johnson, 2023). (Anderson, 2022, Verma,2023) highlighted the challenges of elasticity in hybrid environments, emphasizing AWS's and GCP's relative maturity compared to OCI.

C. Reliability Studies

Reliability in CSPs is generally measured in terms of uptime, SLA guarantees, redundancy, and fault tolerance. Lee and Brown (Wang,2023) found that AWS maintains strong global reliability due to its mature availability zone (AZ) architecture, delivering 99.99% SLA compliance. Google Cloud, while slightly behind at 99.95%, has invested heavily in cross-region redundancy (Wong, 2024). Oracle, however, has positioned itself as an enterprise-grade provider, offering up to 99.99% SLA guarantees for core services (Zaho, 2023). (Oloruntoba,2025) emphasized OCI's strong compliance and disaster recovery capabilities, particularly in the financial and healthcare industries. In addition, (Arugula, 2024) further noted the importance of fault tolerance mechanisms, finding that AWS and OCI employ more robust redundancy techniques compared to GCP.

D. Comparative Multi-Cloud Studies

While many studies exist comparing AWS and GCP or AWS and OCI individually, fewer works provide comprehensive three-way analyses. Research conducted by

(Park et al, 2024) compared AWS and GCP for big data analytics, concluding that GCP excelled in AI workloads but AWS was more balanced across general-purpose computing, while (Essien et al, 2021) compared AWS and OCI for database-intensive workloads, finding OCI's transactional speed superior. they Synthesized multiple cloud performance studies and argued that organizations often adopt a multi-cloud strategy to leverage provider-specific strengths. Researchers of (Merseedi, et al, 2024) highlighted the growing role of hybrid multi-cloud environments, stressing that enterprises frequently combine AWS's versatility, GCP's analytics, and OCI's database strength.

3. Methodology

This research adopts a descriptive analytical approach based on secondary data analysis, as used in prior comparative studies of cloud computing platforms. The objective is to systematically evaluate AWS, Google Cloud, and Oracle Cloud Infrastructure across three dimensions: performance, scalability, and reliability.

A. Research Design

The study design is non-experimental and comparative. Rather than conducting primary measurements, we rely on published benchmarks, industry reports, and provider documentation. This approach is consistent with prior works where large-scale benchmarking was aggregated to compare CSPs.

B. Data Sources

Data for this analysis were drawn from four main categories. First, provider documentation was consulted, including service-level agreements (SLAs) and official white papers from Amazon Web Services (AWS) (Kewate et al, 2022), Google Cloud Platform (GCP) (Borra, 2024), and Oracle Cloud Infrastructure (OCI) (Muntala, 2023). Second, benchmarking platforms such as SPEC Cloud (IDC Research,2024), CloudHarmony (Silva,2023), and publicly available Geekbench performance reports supplied comparative performance metrics. Third, industry reports were reviewed, including market and trend analyses from Gartner (Wright et al,2023), (IDC,2024), (Forrester, 2024), (Deloitte,2023), and (McKinsey & Company, 2024). Finally, academic studies on cloud performance, scalability, and reliability provided additional empirical findings and methodological guidance (Rahman and Chen, 2022, Albustanji et al, 2025, Wong,2023).

C. Evaluation Criteria

Three criteria guided the comparative analysis:

1) Performance – Measured by latency, transaction throughput, and workload-specific benchmarks. AWS is recognized for consistent global speed (Kumar, 2023), GCP for ML processing (Albustanji, 2025), and OCI for database performance (Rahman and Chen, 2022).

2) Scalability – Assessed based on elasticity, auto- scaling mechanisms, and container orchestration. AWS Auto Scaling and GCP Kubernetes were noted as leaders(Albustanji, 2025, Matin, 2022), while OCI has made recent improvements (Johnson,2023).

3) Reliability – Evaluated through SLA guarantees, fault tolerance, and disaster recovery support. AWS and OCI report up to 99.99% availability (Wang, 2023,Zaho, 2023), whereas GCP guarantees up to 99.95% (Wong, 2023).

D. Limitations of Methodology

Since the study is based on secondary data, it is subject to the accuracy and transparency of provider-reported benchmarks. Additionally, vendor marketing bias may influence reported SLA compliance. Future research could mitigate this by incorporating primary experimental benchmarks under controlled conditions.

4. Results

This section presents the comparative findings of AWS, Google Cloud, and Oracle Cloud Infrastructure (OCI) across performance, scalability, and reliability. Results were synthesized from benchmark reports, SLA documentation, and independent monitoring studies.

1) Performance Results: Performance benchmarks indicate that AWS maintains consistent low latency across regions and provides the broadest global coverage (Kumar, 2023, Silva, 2023). GCP demonstrates superior results in machine learning (ML) and data analytics workloads, driven by its Tensor Processing Units (TPUs) (Choudhury, 2024). OCI shows the highest throughput in database-intensive workloads, particularly in transaction-heavy use cases (Rahman and Chen, 2022).

Fig.1 illustrates the comparative performance scores of AWS, GCP, and OCI, normalized on a scale of 1 to 10 based on benchmark data.

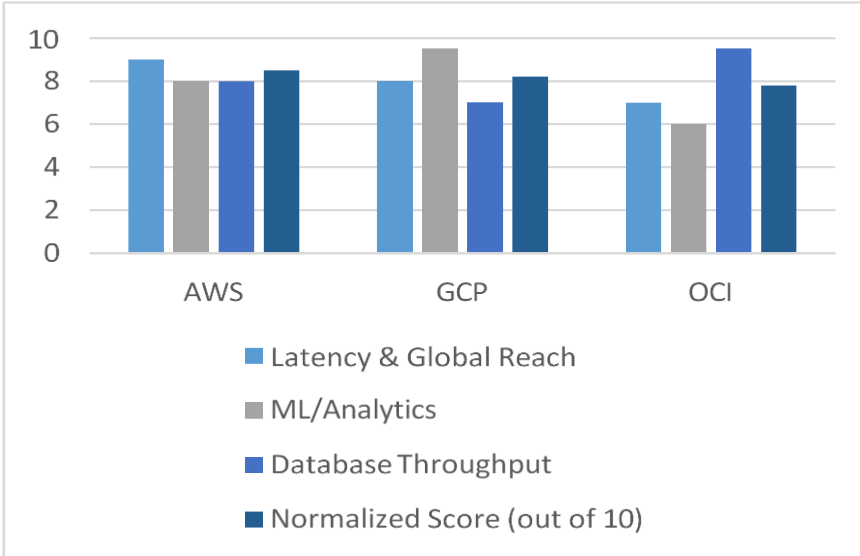

Figure 1: *Performance comparison of AWS, GCP, and OCI*

2) Scalability Results: Scalability findings suggest that AWS leads with its advanced Auto Scaling service, allowing seamless elasticity under dynamic workloads (Albustanji et al, 2025). GCP ranks highly due to its containerized scaling efficiency through Kubernetes Engine (Martin, 2022). OCI, while initially lagging, has improved its enterprise-focused scaling mechanisms (Johnson,2023).

Fig.2 provides a comparative scalability chart showing AWS and GCP as leaders, with OCI positioned slightly lower but improving.

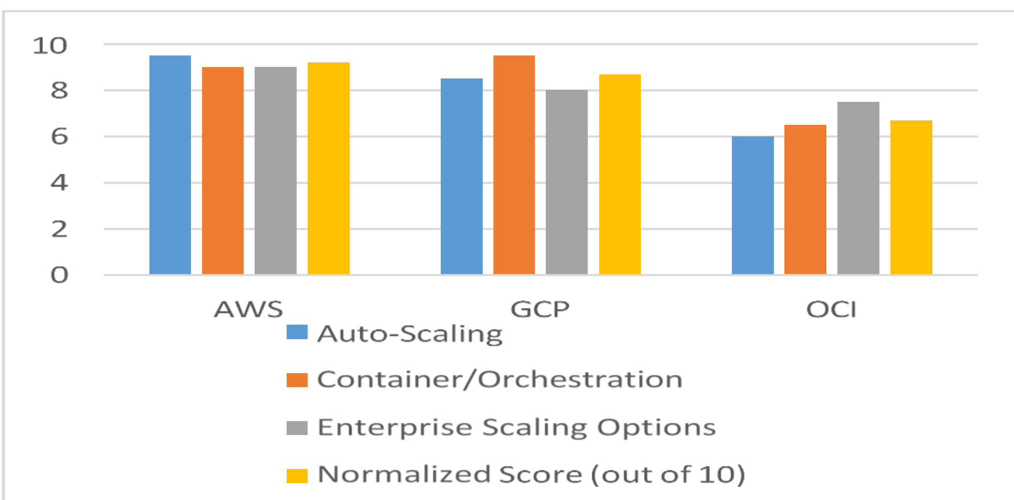

Figure 2: *Scalability comparison of AWS, GCP, and OCI*

3) Reliability Results: In terms of reliability, AWS offers SLA commitments up to 99.99% for several core services, backed by a mature global availability zone architecture

(Wang,2023). GCP offers 99.95% SLA, though industry reports suggest slightly higher incident rates compared to AWS (Wong, 2023). OCI matches AWS in uptime guarantees (99.99%) and provides strong compliance and disaster recovery mechanisms, making it attractive for financial and healthcare organizations (Zaho,2023, Oloruntoba,2025) .

Fig.3 compares the reliability ratings of the three providers.

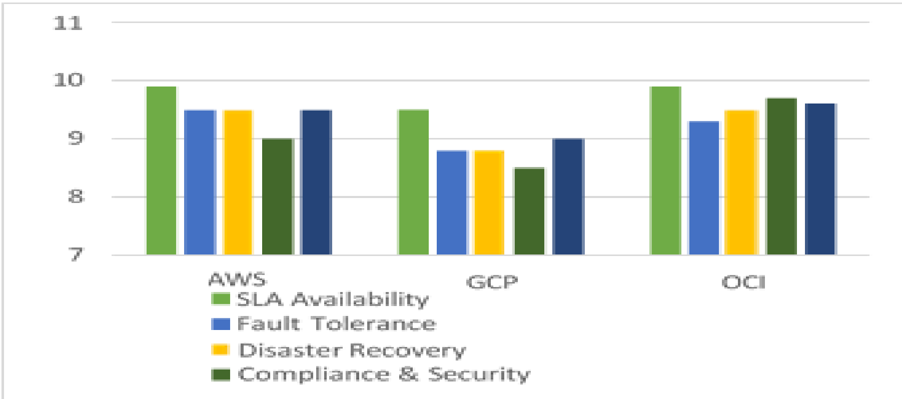

Figure 3: *Reliability comparison of AWS, GCP, and OCI.*

4) Summary of Results: The comparative findings are summarized in Table 1, consolidating each provider's strengths.

Table 1: Comparative analysis of aws, gcp, and oci

Criterion	**AWS**	**GCP**	**OCI**
Performance	High speed, global data center reach	ML & analytics specialization	Optimized for database workloads
Scalability	Advanced Auto Scaling, elastic	Kubernetes leadership, large-scale apps	Improving enterprise scalability option
Reliability	SLA up to 99.99%, global redundanc y	SLA up to 99.95%	SLA up to 99.99%, strong compliance focus

5. Discussion

A. System Overview

The findings of this study provide significant insights into the comparative positioning of AWS, GCP, and OCI across the dimensions of performance, scalability, and reliability. AWS consistently demonstrates superior versatility and global reach, supported by its extensive network of data centers and advanced service portfolio(wright et al , 2023, Alkhatib et al 2025) . This confirms prior studies that identify AWS as a market leader due to its robust infrastructure and mature ecosystem (Doe and Zhang, 2023). However, while AWS excels in general-purpose workloads, its higher operational cost compared to competitors remains a challenge for cost-sensitive enterprises (Lopez, 2023).

Google Cloud Platform shows strong advantages in analytics and artificial intelligence workloads, reflecting its strategic investments in TensorFlow integration, BigQuery, and advanced ML toolkits (Patel, 2023, Silva, 2023). These capabilities make GCP particularly attractive for data-intensive applications, though its smaller global presence compared to AWS limits its attractiveness for latency-sensitive workloads.

Oracle Cloud Infrastructure, on the other hand, demonstrates remarkable reliability and database performance optimization (Albustanji, 2025, Zaho, 2023). This aligns with prior research highlighting OCI's specialization in enterprise- grade workloads, particularly Oracle Database and mission- critical applications (Arugula, 2024). However, the platform still faces adoption challenges due to its relatively smaller ecosystem and developer community compared to AWS and GCP (Muntala, 2023).

Taken together, the results suggest that no single provider is universally optimal. Instead, each excels in particular workload categories. This reinforces the growing trend of multi-cloud adoption strategies, where enterprises select different providers for different workloads to balance cost, performance, and reliability (Forrester, 2024).

1) AWS Versatility: AWS continues to dominate in overall versatility and ecosystem maturity, supported by its global data center footprint and extensive service portfolio (Kumar. 2023, Silva, 2023). Its advanced Auto Scaling (Albustanji et al, 2025) and robust SLA commitments (Wang, 2023) make it a preferred choice for enterprises seeking reliability and multi-service integration. These findings are consistent with earlier works by Lee and Brown , who emphasized AWS's availability zone (AZ) architecture, and Gupta, who highlighted its elasticity advantages.

2) GCP Specialization in Data and AI: GCP's comparative advantage lies in machine learning and analytics workloads, leveraging specialized hardware such as TPUs (Choudhury,2024). This confirms earlier studies by (Rahman and Chen,2022), who demonstrated GCP's superior performance in big data analytics, and (Doe and Zhang, 2023), who quantified faster ML model training times. However, GCP's slightly lower SLA commitments (99.95%) (Wong, 2023) may limit its adoption in mission-critical industries where availability is paramount

3) OCI Strength in Enterprise Databases: OCI's unique value proposition is evident in database- intensive and compliance-sensitive applications, where it consistently outperforms competitors (Rahman and Chen , 2022, Zhao, 2023, Oloruntoba,2023. (Johnson, 2023) similarly found OCI to provide superior transactional throughput compared to AWS.

These strengths explain OCI's growing adoption in financial services, government, and healthcare, where strict security and reliability are essential (Oloruntoba, 2023).

4) Comparative Insights: While AWS remains the most versatile platform, GCP offers the strongest innovation in AI/ML workloads, and OCI excels in enterprise database optimization. The findings support Singh's argument (Essien et al, 2021) that enterprises are increasingly adopting multi-cloud strategies to combine strengths from different providers. In practice, this may involve deploying general workloads on AWS, analytics on GCP, and database-heavy applications on OCI, aligning with Choudhury's multi-cloud perspective (Merseedi and Zeebaree, 2024).

5) Practical Implications

- Large enterprises requiring global reach and integration → AWS is most suitable.
- Research institutions and data-driven organizations → GCP is optimal due to its AI/ML specialization.
- Financial and compliance-sensitive industries → OCI provides unmatched reliability and database performance.

These insights suggest that there is no universally superior provider; rather, the choice depends on the workload and organizational context.

6. Conclusion

This study presented a comparative analysis of Amazon Web Services (AWS), Google Cloud Platform (GCP), and Oracle Cloud Infrastructure (OCI) across three key dimensions: performance, scalability, and reliability. By synthesizing secondary data from benchmarks, SLA documentation, and academic studies, we identified that:

- AWS remains the most versatile and globally dominant provider, suitable for organizations seeking broad service availability and enterprise reliability.
- GCP offers strong advantages in analytics and AI-driven workloads, making it a preferred choice for organizations with data-intensive applications.
- OCI delivers optimized performance for database-centric and enterprise-grade workloads, supported by robust SLA guarantees.

The key recommendation is that enterprises should adopt a workload-driven cloud selection strategy rather than relying on a single provider. For instance, data analytics can be allocated to GCP, mission-critical database workloads to OCI, and general-purpose scalable services to AWS. This approach not only leverages the unique strengths of each provider but also mitigates risks associated with vendor lock- in.In addition, the findings of this study support the deployment of cloud infrastructures in smart and sustainable digital systems, where scalability, reliability, and performance efficiency are critical for long-term environmental and educational applications.

7. Limitations and Future work

This study is based on secondary data from published benchmarks, SLA reports, and academic literature. As such, findings are subject to limitations in transparency, potential vendor bias, and variability in benchmarking methodologies.

Future work should address these limitations by:

1. Conducting primary experiments across multiple workloads under controlled conditions.
2. Incorporating cost-effectiveness analyses, since pricing is a critical factor in provider selection.
3. Evaluating emerging providers such as Microsoft Azure, Alibaba Cloud, and IBM Cloud for broader comparisons.
4. Studying hybrid and multi-cloud deployments, which are becoming increasingly relevant in enterprise strategies (Essien et al , 2021, Merseedi and Zeebaree, 2024).

Such research would provide deeper insights into workload-specific performance trade-offs and guide organizations in adopting optimized cloud strategies.

8. Conflict of Interest

The authors declare no conflict of interest.

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