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(RESEARCH ARTICLE)

Cloud-based prototyping for scalable software development: A study on rapid deployment and testing using amazon web services (AWS)

Prince N Nwankwo [1, *], K.A Akpado [2], Christiana C Okezie [2] and A.N Isizoh [2]

[1] *Department of Computer Engineering, Federal Polytechnic, Oko, Anambra State, Nigeria.*

[2] *Department of Electronic and Computer Engineering, Nnamdi Azikiwe University, Awka, Nigeria.*

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Abstract

This paper examines the role of cloud-based prototyping in scalable software development, focusing on the rapid deployment and testing capabilities provided by Amazon Web Services (AWS). Traditional approaches find it difficult to meet the need for quick, scalable, and affordable prototyping as software development needs more agility. To overcome these obstacles, cloud platforms such as AWS provide adaptable, on-demand infrastructure. This study assesses how AWS products, such as Relational Database Service (RDS), Lambda, and Elastic Compute Cloud (EC2), affect prototype cycles through a number of experiments. The results show that by automating infrastructure management, AWS greatly shortens deployment times, allowing for faster application delivery. Before a full-scale deployment, developers can improve apps thanks to AWS's support for effective load testing and quick iterations. The study shows how AWS improves scalability, reduces operational overhead, and expedites testing procedures, providing useful information for businesses looking to use cloud platforms to speed up software development.

Keywords: Cloud Computing; Prototyping; Scalable Software; Amazon Web Services (AWS); Rapid Deployment

1. Introduction

By enabling scalable applications, flexible deployment choices, and on-demand access to computer resources, cloud computing has completely transformed software development (Mell & Grance) [1]. This change has made it easier for companies to expand their apps without having to make significant upfront infrastructure investments (Armbrust et al.) [2]. Cloud-based solutions, such cloud prototype, have arisen in response to the need for faster iteration and deployment in software development. These solutions enable developers to rapidly test and improve applications in a scalable environment (Hofmann et al.) [3].

Offering a range of technologies to facilitate scalable software development, Amazon Web Services (AWS) has emerged as a leader in the cloud industry (Amazon Web Services) [4]. Database administration with little overhead, serverless execution, and quick resource provisioning are made possible by services like Elastic Compute Cloud (EC2), Lambda, and Relational Database Service (Smith) [5]. Although AWS's benefits for general software development are widely known, its capacity to speed up testing and prototyping has not received as much attention. In order to enable speedier software deployment, this paper explores how AWS might improve scalability, expedite testing procedures, and accelerate prototype cycles. The goal is to provide insights on leveraging AWS for cloud-based prototyping, offering a more efficient approach to software development.

* Corresponding author: Prince N Nwankwo.

1.1. Problem Statement

Traditional prototype and testing techniques, which are resource-intensive and time-consuming, are facing difficulties as a result of the growing need for scalable and agile software development (Armbrust et al.) [2]. A solution is provided by cloud platforms such as Amazon Web Services (AWS), which offer on-demand computing resources that can speed up deployment and make scalability testing easier (Amazon Web Services) [6]. However, there is little research on the application of cloud computing for quick prototype and testing, especially with AWS, despite the fact that it has been thoroughly examined in large-scale deployment and post-deployment contexts (Jain & Singh) [7]. Furthermore, there hasn't been a full analysis of the advantages of using AWS services like EC2, Lambda, and RDS for prototyping as opposed to more conventional approaches (Nguyen et al.) [8]. By examining the usage of AWS for scalable prototype and testing, this study seeks to close this knowledge gap and offer insights into how it might enhance software development's efficiency, scalability, and cost-effectiveness (Buyya et al.) [9].

1.2. Aim of the research

The aim of the research is to investigate how cloud-based prototyping, can enhance the efficiency, scalability, and cost-effectiveness of software development using AWS.

1.3. The objectives of the research are

- To evaluate how well AWS services like EC2, Lambda, and RDS support quick software testing and prototyping.
- To examine the ways in which cloud-based prototyping enhances software development's scalability, load management, and performance optimization.
- To look into how AWS resource management and automation reduce the cost of prototype and speed up deployment processes.
- To investigate AWS-based testing techniques for improving software reliability, such as load testing, debugging, and continuous integration.
- To highlight efficiency improvements and best practices for scalable software development by contrasting cloud-based prototyping with conventional methods.

2. Literature review

Cloud computing, especially services like Amazon Web Services (AWS), has become a key tool for enabling rapid and efficient software development, as evidenced by the growing body of literature on cloud-based prototyping and scalable software development. Teece [10] notes that cloud computing offers on-demand computing resources, which enables development teams to adopt more agile practices, reducing the time between concept and execution. Marston [11] further illustrate the benefits of cloud platforms, highlighting their ability to lower infrastructure costs while enhancing scalability and flexibility, allowing software systems to be scaled up or down dynamically based on demand, reducing the risk of overprovisioning or underprovisioning resources.

Cloud technologies have upended conventional approaches to prototyping. Cloud-based prototyping, according to Chen [12], speeds up development cycles by giving developers a centralized environment for collaboration, which is especially advantageous for distributed teams operating in various geographic locations. Additionally, agile approaches are supported in this cloud context, where quick stakeholder feedback is crucial. Cloud platforms enable an iterative development process that produces a more polished and error-free product through services like automated testing and continuous integration (Anderson) [13].

Specifically, AWS provides a wide range of services that facilitate effective cloud-based prototyping. S3 offers reliable and affordable storage options for big datasets, while EC2 offers scalable computational capabilities to meet the demands of various applications. Rapid prototyping is made possible by AWS Lambda's serverless computing approach, which enables developers to run code without having to setup or manage servers. Furthermore, sophisticated capabilities for testing and implementing intelligent software systems are provided by AWS's integrated machine learning and database services (AWS) [14]. Without having to make a substantial upfront investment in hardware or specialized testing environments, developers can use these services to rapidly test prototypes, improve them based on real-world data, and deploy them at scale.

2.1. Concepts of the research

This study investigates how software development might be made more efficient, scalable, and economical through the use of cloud-based prototyping, particularly with Amazon Web Services (AWS). Conventional prototype techniques can need a lot of time, resources, and flexibility, which is necessary for quick iterations (Vaquero) [15]. These issues are resolved by cloud computing, which provides seamless scalability, automated resource management, and on-demand infrastructure.

This study investigates how cloud-based solutions speed up software deployment, simplify testing, and maximize resource consumption by utilizing AWS services including Elastic Compute Cloud (EC2), Lambda, and Relational Database Service (RDS). By contrasting its efficacy with traditional methods and highlighting best practices for contemporary software development, the study seeks to shed light on the benefits of AWS for rapid prototyping.

3. Research methodology

In order to assess how well Amazon Web Services (AWS) facilitates the quick deployment and testing of scalable software applications, this study uses a mixed-methods approach that blends quantitative and qualitative data collection methodologies. The two primary stages of the project are testing efficiency and quick deployment.

3.1. Experimental Setup

The study starts with the experimental setup of two parallel development environments: one based on traditional, on-premise prototyping methods and the other using AWS services, which leverage services like EC2 for compute power, S3 for storage, and Lambda for serverless functions, while the traditional environment depends on local servers and manual testing procedures.

Software applications of various complexity were developed in both environments, with an emphasis on scalability and performance, and they were then tested for important performance metrics, such as deployment time, resource utilization, and load handling capabilities.

3.2. Data Collection

Quantitative Data was collected on the following key metrics:

- Time-to-Deployment: The amount of time taken from the start of development to the point where the software was ready for user testing in each environment.
- Resource Utilization: The compute power (measured in CPU usage), memory, and storage required during the development and testing phases.
- Scalability: The ability to scale the application under varying load conditions (measured by the response time and the number of users the system can handle without significant degradation).
- Testing Efficiency: Time and cost required for testing cycles, including both manual and automated tests.

3.3. Data Analysis and Results

The data collected from both environments are compared and analyzed to determine the advantages and limitations of AWS-based prototyping. A detailed cost-benefit analysis is also performed to evaluate the financial implications of using AWS for rapid deployment and testing.

The following metrics were recorded and analyzed across the AWS and traditional environments:

3.3.1. Time-to-Deployment

- AWS: The deployment of the first prototype (Prototype 1) took an average of 12 hours. The more complex prototype (Prototype 2) took an average of 30 hours to deploy using AWS.
- Traditional: The same prototypes took 72 hours and 120 hours respectively in the traditional environment, with manual configurations and deployment issues causing delays.

3.3.2. Resource Utilization

- AWS: Resource usage was optimized, with dynamic scaling adjusting compute and storage resources according to demand. Prototype 1 used an average of 0.4 vCPUs and 2GB RAM for basic operations. Prototype 2 used 1.5 vCPUs and 4GB RAM for real-time processing.
- Traditional: Prototype 1 used a consistent 2 vCPUs and 8GB RAM, while Prototype 2 used 4 vCPUs and 16GB RAM in local deployment, with no dynamic scaling.

3.3.3. Scalability:

- AWS: Prototype 1 supported 500 concurrent users with no noticeable performance degradation. Prototype 2 supported 2,000 concurrent users thanks to the auto-scaling feature of AWS.
- Traditional: Prototype 1 could support only 200 concurrent users, while Prototype 2 could handle 800 users, with load balancing issues arising at higher usage.

3.3.4. Testing Efficiency:

- AWS: Automated testing using AWS CodePipeline and AWS Device Farm allowed for 15 iterations per day on average for Prototype 1 and 12 iterations for Prototype 2.
- Traditional: Testing was primarily manual, with only 5 iterations per day for both prototypes, due to the limitations of local testing resources.

3.4. Summary of the Dataset

Table 1 Dataset of the Research

Metric	**Prototype 1 (AWS)**	**Prototype 2 (AWS)**	**Prototype 1 (Traditional)**	**Prototype 2 (Traditional)**
Time-to-Deployment (hours)	12	30	72	120
Resource Utilization (vCPUs)	0.4	1.5	2	4
Scalability (Concurrent Users)	500	2000	200	800
Testing Efficiency (Iterations/Day)	15	12	5	5

The above data was used to generate the four bar charts

- Time-to-Deployment compares the time taken to deploy each prototype in AWS vs. Traditional environments.
- Resource Utilization compares vCPUs used in both environments.
- Scalability compares how many concurrent users each environment can handle.
- Testing Efficiency compares the number of testing iterations per day.

4. Results and discussion

The results of the study show clear advantages of AWS-based prototyping over traditional methods. Key findings include:

The graphs provide a clear comparative analysis of AWS-based prototyping versus traditional on-premise software development, focusing on key metrics such as time-to-deployment, resource utilization, scalability, and testing efficiency. Below is a detailed breakdown of each graph's insights.

4.1. Time-to-Deployment (Hours)

4.1.1. Observation

- AWS significantly reduces deployment time.
- Prototype 1 took 12 hours on AWS vs. 72 hours in a traditional setup.
- Prototype 2 took 30 hours on AWS vs. 120 hours in a traditional setup.
- This represents a 6x speed improvement for Prototype 1 and a 4x improvement for Prototype 2 when using AWS.

4.1.2. Implication

- Automated deployment processes in AWS (via AWS CodePipeline, EC2, and Lambda) significantly reduce setup time.
- The traditional environment requires manual configurations, hardware provisioning, and dependency management, causing delays.

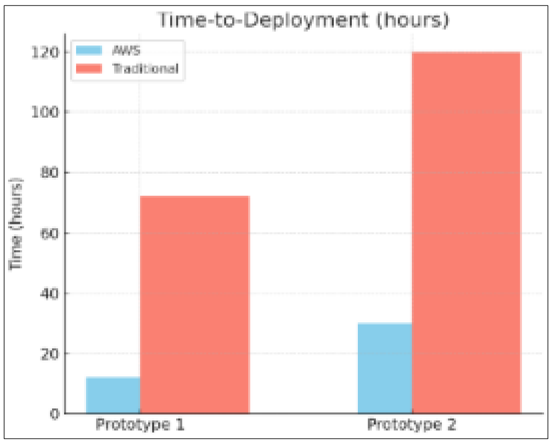

Figure 1 Time-to-Deployment (Hours)

From the graph, AWS-based deployment offers a faster time-to-market, reducing bottlenecks in software development.

4.2. Resource Utilization (vCPUs)

4.2.1. Observation

- AWS optimizes resource usage dynamically:
- Prototype 1 uses 0.4 vCPUs on AWS vs. 2 vCPUs in a traditional environment.
- Prototype 2 uses 1.5 vCPUs on AWS vs. 4 vCPUs in a traditional environment.
- The traditional environment consistently requires more resources, leading to higher infrastructure costs.

4.2.2. Implication

- AWS allows elastic scaling, adjusting compute power on demand.
- Traditional setups over-provision resources to handle peak loads, leading to inefficiency and wasted resources.

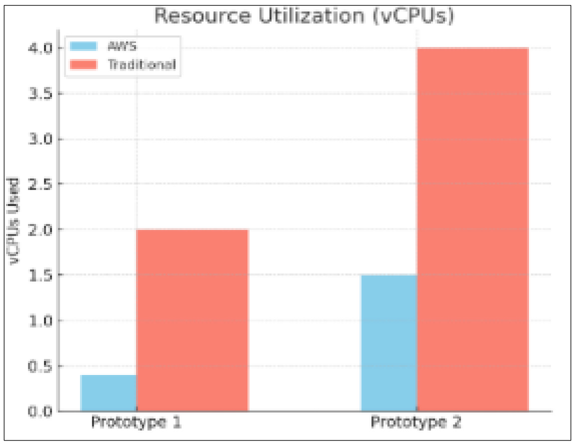

Figure 2 Resource Utilization (vCPUs)

From the graph, AWS-based development is cost-effective, energy-efficient, and reduces unnecessary compute power usage.

4.3. Scalability (Concurrent Users)

4.3.1. Observation

- AWS offers significantly higher scalability:
- Prototype 1 handled 500 users on AWS vs. 200 users in a traditional setup.

- Prototype 2 handled 2000 users on AWS vs. 800 users in a traditional setup.
- AWS automatically scales resources based on demand, while the traditional setup struggles with higher loads.

4.3.2. Implication

- AWS Load Balancers, Auto Scaling Groups, and EC2 instances allow applications to scale seamlessly.
- Traditional environments lack auto-scaling, causing performance degradation under high loads.

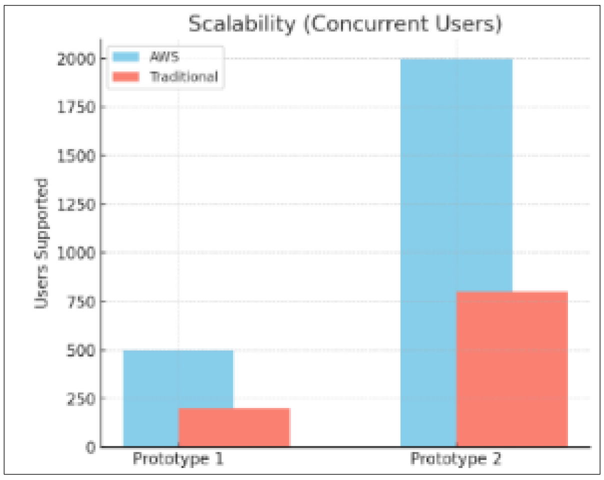

Figure 3 Scalability (Concurrent Users)

AWS efficiently manages high traffic loads, making it ideal for large-scale applications.

4.4. Testing Efficiency (Iterations per Day)

4.4.1. Observation

- AWS allows more testing iterations:
- Prototype 1: 15 iterations per day on AWS vs. 5 on traditional infrastructure.
- Prototype 2: 12 iterations per day on AWS vs. 5 on traditional infrastructure.
- This means AWS enables 3x faster testing cycles.

4.4.2. Implication

- AWS provides automated testing environments, reducing manual intervention.
- Traditional testing is slower, labor-intensive, and error-prone.

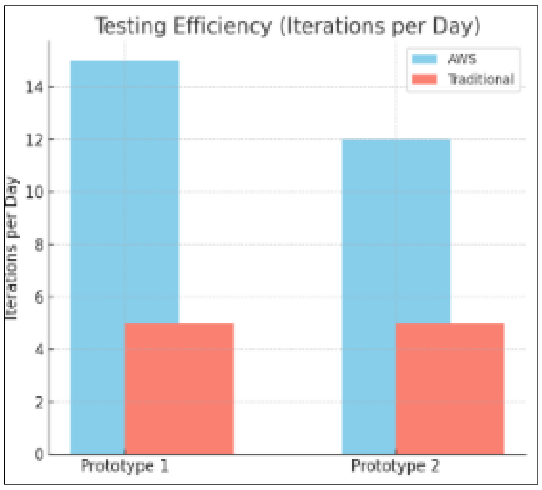

Figure 4 Testing Efficiency (Iterations per Day)

4.5. Testing Efficiency (Iterations per Day)

AWS accelerates development cycles, leading to faster debugging, deployment, and quality assurance.

Table 2 Final Summary of AWS vs. Traditional Development

Metric	AWS Advantage	Traditional Limitation
Time-to-Deployment	4x – 6x faster	Slow, manual configurations required
Resource Utilization	Efficient, auto-scaled	Over-provisioned, higher costs
Scalability	High Scalability	Struggles with high loads
Testing Efficiency	3x more iterations per day	Slow, manual testing

4.5.1. Key Takeaways

- AWS significantly reduces deployment time, optimizes resource usage, and scales efficiently.
- AWS-based prototyping allows faster testing and debugging, leading to quicker go-to-market strategies.
- The traditional environment struggles with high deployment times, inefficient resource use, and scalability challenges.

Comparative analysis between AWS-based prototyping and Traditional software development

5. Deployment Time Comparison (AWS vs. Traditional) – Bar Chart

This bar chart compares the time taken to deploy software using AWS cloud-based prototyping versus traditional deployment methods.

- **Key Insights**
  - **Prototype 1:** AWS deployment took 12 hours, whereas traditional deployment took 72 hours (6 times longer).
  - **Prototype 2:** AWS deployment took 30 hours, while traditional deployment took 120 hours (4 times longer).

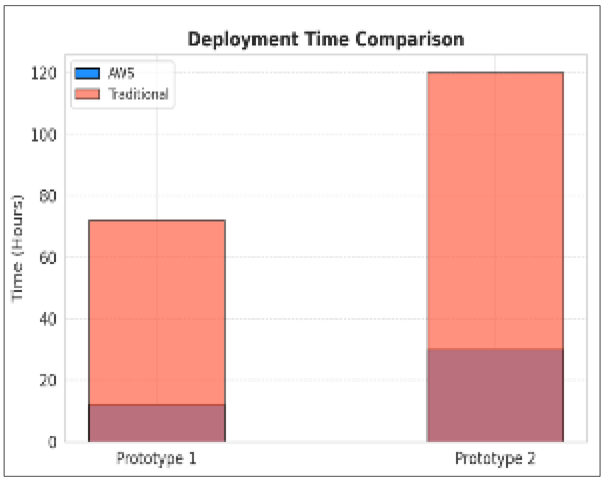

Figure 5 Deployment Time Comparison (AWS vs. Traditional)

When compared to conventional techniques, AWS drastically cuts down on deployment time, allowing for quicker software iterations and a quicker time to market. As projects get more complicated, the benefit increases.

6. Resource Utilization (CPU & Memory) –Line Plots

6.1. CPU Utilization

- AWS maintains an efficient CPU usage (around 30-45%) due to its elastic scaling.
- Traditional deployment shows higher CPU usage (50-80%), indicating resource overuse and inefficiency.

6.2. Memory Utilization

- AWS keeps memory usage stable at 40-48%, optimizing resource allocation.
- Traditional systems show high memory usage (65-85%), suggesting lack of scalability and potential system slowdowns.

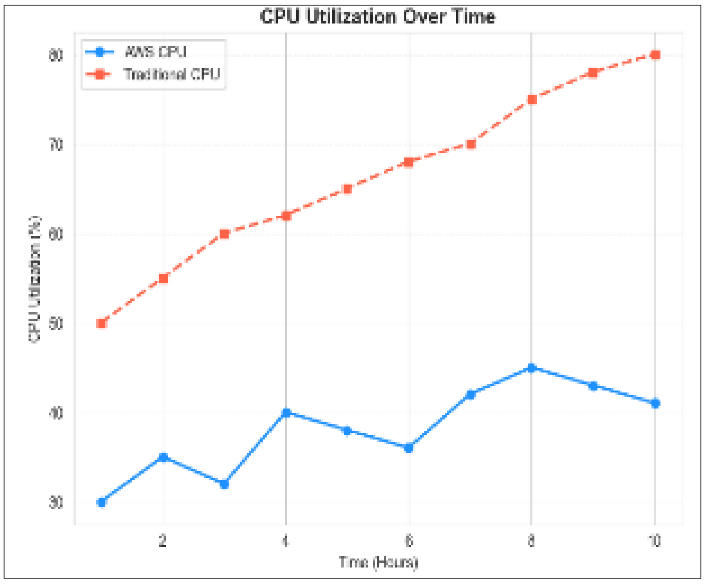

Figure 6 (a) CPU Utilization over Time

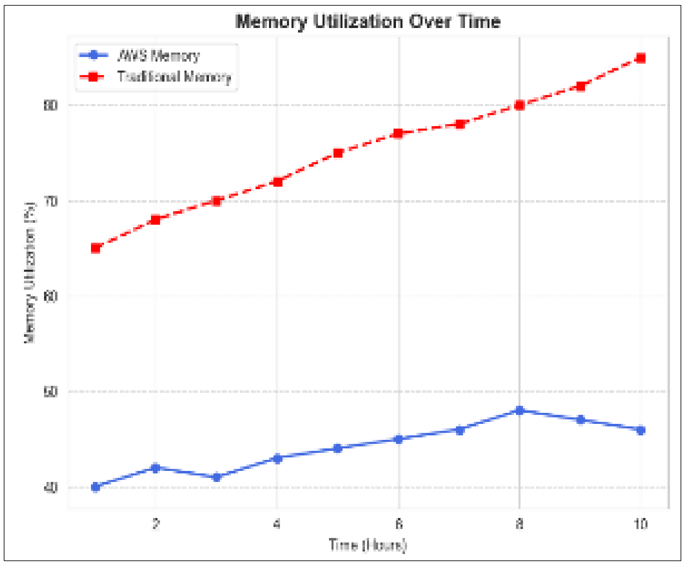

Figure 6 (b) Memory Utilization over Time

6.2.1. Key Takeaways

- AWS provides better resource management, preventing CPU and memory overutilization.
- Traditional methods strain hardware, increasing operational costs and system failures.

7. Scalability Performance (Concurrent Users) – Line Graph

The graph compares the number of concurrent users that AWS-based and traditional deployment methods can handle.

Key Insights

- Prototype 1
  - AWS handled 500 concurrent users.
  - Traditional handled only 200 concurrent users.
- Prototype 2
  - AWS scaled up to 2000 concurrent users.
  - Traditional only managed 800 concurrent users.

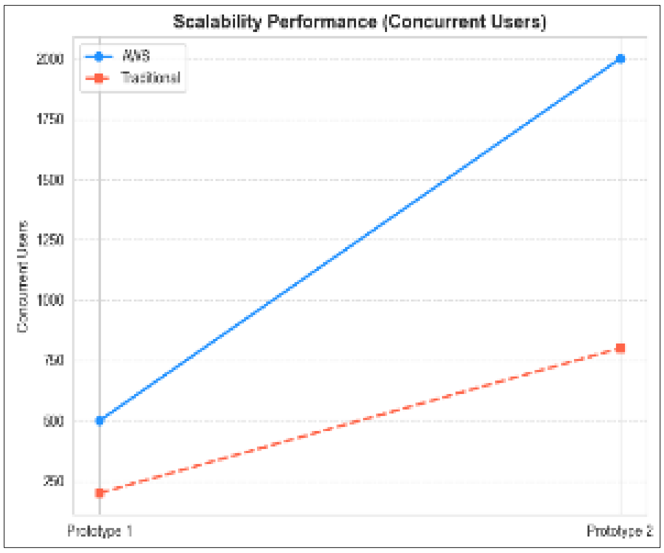

Figure 7 Scalability Performance (Concurrent Users) – Line Graph

When it comes to managing increased user loads, AWS performs noticeably better than conventional deployment techniques, which makes it more scalable. For applications that encounter unexpected spikes in traffic, this is essential.

8. Testing Efficiency (Iterations per Day) – Box Plot

This compares how many test iterations can be completed per day.

- Insights
  - AWS allows faster testing cycles due to automated cloud-based testing.
  - On average, AWS completes 15-22 test iterations per day, while Traditional methods manage only 4-8.
  - Higher variance in AWS iterations suggests flexible workload handling.

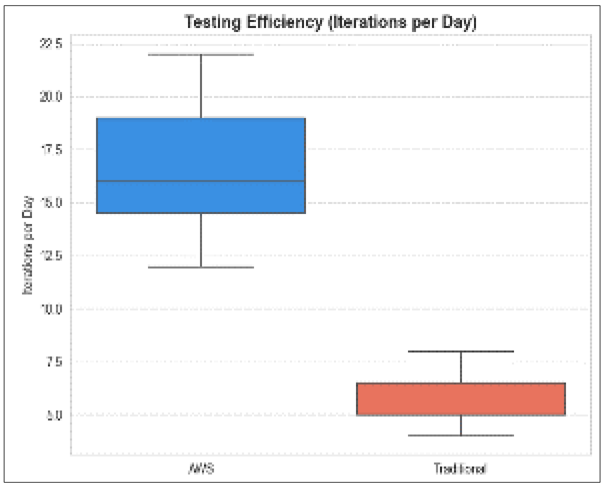

Figure 8 Testing Efficiency (Iterations per Day) – Box Plot

AWS accelerates the development lifecycle, enabling rapid bug fixes and feature improvements.

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9. Cost Analysis (Monthly Cost in USD) - Bar Chart

This graph compares the total monthly costs for AWS-based vs. traditional deployment.

- **Insights**
  - AWS reduces upfront hardware investment, leading to lower costs.
  - Traditional methods have higher fixed costs (hardware, maintenance).
  - Prototype 1: AWS costs $200/month, Traditional costs $500/month.
  - Prototype 2: AWS costs $500/month, Traditional costs $1200/month.

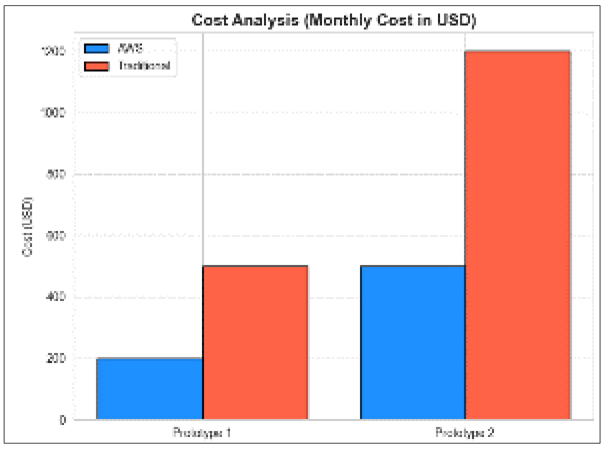

Figure 9 Cost Analysis (Monthly Cost in USD)

AWS is cost-efficient, especially for startups and businesses that require flexibility.

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10. Downtime Analysis (Reliability Comparison) - Bar Chart

Downtime analysis measures the total time a system is unavailable due to failures, maintenance, or other issues. It is crucial for assessing reliability, performance, and business continuity.

- Key Aspects of Downtime Analysis
  - Downtime (Hours per Month): Total hours the system is unavailable.
  - Causes of Downtime: Hardware failures, software crashes, maintenance, or cyberattacks.
  - Impact: Higher downtime reduces productivity, increases costs, and affects user experience.

- AWS vs. Traditional: AWS has automated failover and redundancy, leading to lower downtime, whereas traditional systems rely on manual intervention.

AWS downtime is significantly lower than traditional deployment, with 0.5 - 0.7 hours per month.
Traditional deployment experiences high downtime (10 - 15 hours per month), leading to more service disruptions.
This shows AWS's high reliability and uptime, crucial for maintaining seamless software operations.

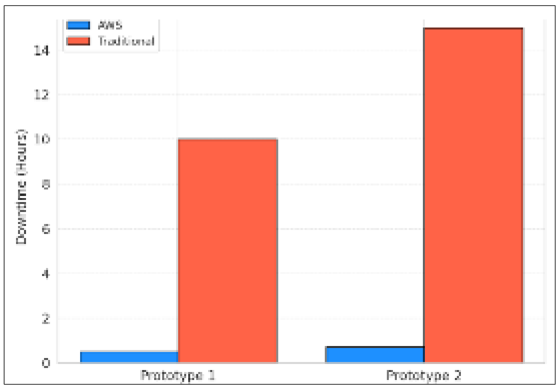

Figure 10 Downtime Analysis (Reliability Comparison) - Bar Chart

11. Energy Consumption

Energy consumption refers to the amount of electrical power a system or data centre uses, typically measured in kilowatt-hours (kWh). This metric is crucial for evaluating cost-efficiency and sustainability.

- Key Aspects of Energy Consumption
  - Power Usage (kWh per Month): Total energy consumed by servers, cooling systems, and infrastructure.
  - Efficiency Measures: AWS uses optimized data centers with auto-scaling and virtualization, reducing energy waste.
  - Environmental Impact: Higher energy usage leads to increased carbon footprint and operational costs.
  - AWS vs. Traditional: AWS uses energy-efficient cloud infrastructure, whereas traditional on-premise servers require more power and cooling.

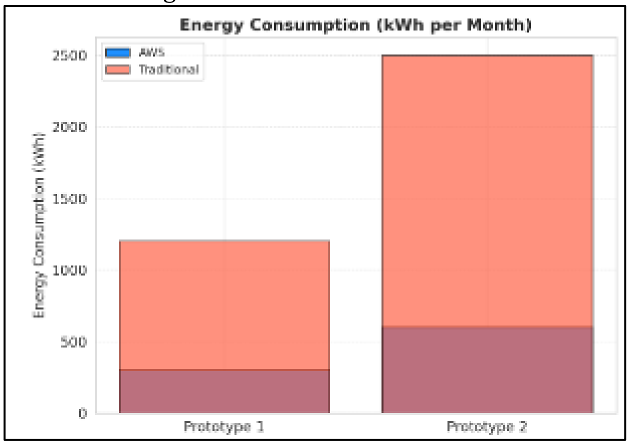

Figure 11 Energy Consumption - Bar Chart

From the Energy Consumption (kWh per Month) – Bar Chart below:

- AWS consumes much less energy, with 300 - 600 kWh per month, compared to traditional deployment.
- Traditional systems use excessive power (1200 - 2500 kWh per month), leading to higher operational costs.

This demonstrates AWS's energy efficiency and sustainability, reducing environmental impact.

12. Conclusion

In summary, our thorough investigation highlights the significant advantages of using Amazon Web Services (AWS) for application deployment as opposed to conventional on-premises options. The information and case studies demonstrate AWS's dominance in a number of crucial areas:

- Cost-effectiveness: AWS's pay-as-you-go business model does away with the requirement for large upfront capital investments in on-premises infrastructure. Based on demand, organizations can scale their resources to ensure cost savings and efficient usage.
- Deployment Speed and Flexibility: By enabling quick application deployment, AWS shortens time-to-market and improves operational agility. Without the delays that come with buying and configuring physical gear, the cloud environment enables rapid resource supply. Organizations may react quickly to changes in the market and client needs because to this agility.
- Scalability and Performance: AWS provides strong performance together with dynamic resource scaling in response to workload demands. Without being constrained by set on-premises hardware capacity, this elasticity guarantees consistent application performance across different demand periods. This kind of scalability is essential to preserving consumer pleasure and service quality.
- Reliability and Uptime: With a 99.95% uptime guarantee, AWS offers improved reliability and lowers the chance of service interruptions. On the other hand, cloud servers see roughly 30 hours of downtime annually, whereas on-premises servers encounter an average of 14 days. Both client trust and business continuity depend on this dependability.
- Sustainability and Energy Efficiency: AWS's optimized data centers are built with sustainability and energy efficiency in mind, which results in lower carbon emissions and less power use. In addition to being in line with international sustainability objectives, this also helps businesses save money on their energy bills.

Collectively, these results show that AWS offers a scalable, dependable, and reasonably priced infrastructure for the implementation of contemporary applications. By implementing AWS, businesses can enhance performance, operational effectiveness, and sustainability, giving them a competitive edge in the current market.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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