A MULTI-CRITERIA MODEL FOR EVALUATING THE EFFICIENCY OF CLOUD COMPUTING TECHNOLOGIES IN THE DIGITAL ECONOMY

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Abstract:*The article analyzes the efficiency of cloud computing technologies in the context of the digital economy and proposes a multi-criteria evaluation model. The study considers cloud computing not only as an infrastructure service, but also as a managerial tool that affects costs, scalability, productivity, data accessibility and innovation speed. The proposed model combines economic indicators such as total cost of ownership and operational savings with technical indicators such as resource utilization, availability, latency, security and elasticity. A formula-based efficiency index and an analytical comparison of on-premise, private cloud, public cloud and hybrid cloud approaches are presented. The results show that the effectiveness of cloud computing depends on workload type, governance maturity, integration quality and the ability to continuously optimize resources.*

Keywords: *digital economy, cloud computing, efficiency analysis, total cost of ownership, scalability, elasticity, hybrid cloud, information systems, digital transformation.*

INTRODUCTION

The development of the digital economy is directly connected with the ability of organizations to process data quickly, launch new digital services and adapt information systems to changing demand. Traditional local infrastructure often requires large initial investment, long procurement cycles and continuous maintenance. In contrast, cloud computing provides computing power, storage, software platforms and business applications as flexible services. This makes cloud technologies an important foundation for digital transformation in enterprises, public administration, education, healthcare, finance and service sectors.

However, the transition to the cloud does not automatically guarantee efficiency. If cloud resources are not properly selected, configured and monitored, the organization may face unnecessary monthly costs, security risks, integration problems and service quality issues. For this reason, cloud adoption must be based on measurable criteria. A correct efficiency analysis should include both economic and technical dimensions: cost reduction, resource utilization, service availability, scalability, data protection and management transparency.

The aim of this article is to develop a multi-criteria model for evaluating the efficiency of cloud computing technologies in the digital economy. The model is intended to support managerial decision-making before and after cloud migration. It helps answer three practical questions: whether cloud computing is economically justified, which cloud deployment model is more suitable and what optimization actions are needed after implementation.

2. Theoretical Background and Research Gap

Cloud computing is generally understood as a model that provides network access to configurable computing resources such as servers, storage, databases, applications and services. In practice, cloud services are implemented through three main service models: infrastructure as a service, platform as a service and software as a service. These models differ by the level of control given to the user and the level of responsibility carried by the provider. Infrastructure services provide flexible virtual machines and storage; platform services support application development and deployment; software services deliver ready-to-use applications.

From the perspective of the digital economy, cloud computing performs several important functions. First, it reduces the barrier to launching digital products because organizations do not need to purchase all hardware in advance. Second, it supports data-driven management because storage and analytics services can be scaled according to demand. Third, it enables remote work and distributed service delivery. Fourth, it creates a technological basis for artificial intelligence, big data analytics, internet of things and digital platforms.

The research gap is that many studies and institutional discussions evaluate cloud computing only through cost reduction or only through technological convenience. Such a narrow view is not sufficient for managerial decisions. A cloud solution can be cheap but unreliable, secure but expensive, or scalable but poorly integrated with existing systems. Therefore, efficiency should be evaluated through a unified model that combines financial, technical, organizational and security indicators.

3. Proposed Multi-Criteria Efficiency Model

The proposed model treats cloud efficiency as an integrated result of economic savings, service quality, resource utilization, scalability and risk control. Figure 1 presents the general logic of the model. Digital services generate workloads, workloads consume cloud resources, resources create costs and service quality indicators, and management decisions are made according to the calculated efficiency index.

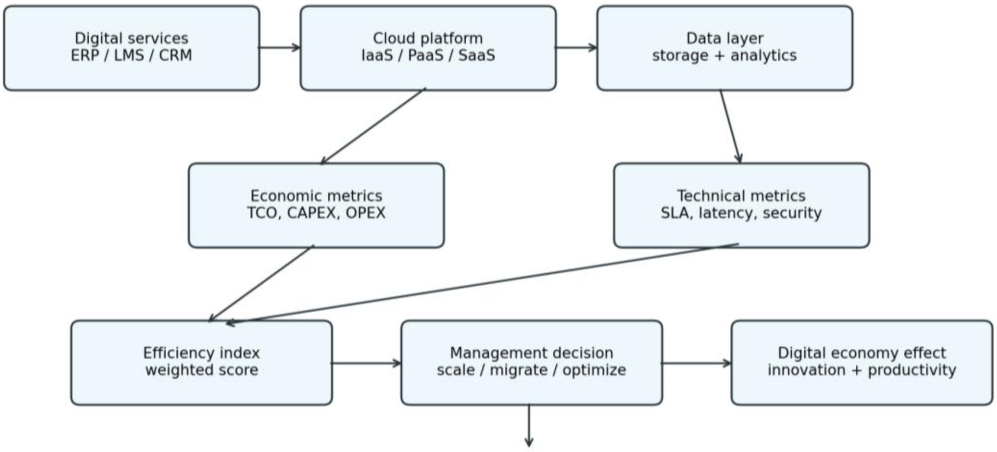

Figure 1. Conceptual model for evaluating cloud computing efficiency in the digital economy.

The total cost of cloud use can be expressed as follows:

TCO_cloud = C_compute + C_storage + C_network + C_security + C_support + C_migration (1)

In Eq. (1), C_compute represents the cost of computing resources, C_storage is data storage cost, C_network is traffic and connectivity cost, C_security includes protection and compliance expenses, C_support is technical support cost and C_migration is migration or integration cost. This formula is useful because it prevents the organization from comparing only the monthly server price and ignoring hidden operational costs.

The resource utilization coefficient is calculated as follows:

U = R_used / R_allocated (2)

Here, R_used is the average used resource volume and R_allocated is the allocated or paid resource volume. A low value of U means that the organization pays for unused capacity. A very high value can indicate performance risk. Therefore, cloud efficiency requires continuous balancing between cost saving and service reliability.

The integrated efficiency index is proposed in the following form:

E_cloud = α_1S_cost + α_2S_avail + α_3S_perf + α_4S_scale + α_5S_sec − α_6S_risk (3)

In Eq. (3), S_cost is normalized cost saving, S_avail is availability score, S_perf is performance score, S_scale is scalability score, S_sec is security score and S_risk is risk score. Coefficients $\alpha_1 \ldots \alpha_6$ reflect the priorities of the organization. For example, a financial organization can assign higher weight to security, while an educational platform can assign higher weight to scalability and accessibility.

4. Evaluation Algorithm

The evaluation process should not be limited to a one-time calculation before migration. Cloud efficiency changes over time because workloads, user numbers, prices, data volume and security requirements also change. Therefore, the proposed algorithm is cyclical. It begins with workload data collection, continues with resource and cost calculation, evaluates service quality and risks, and ends with optimization recommendations.

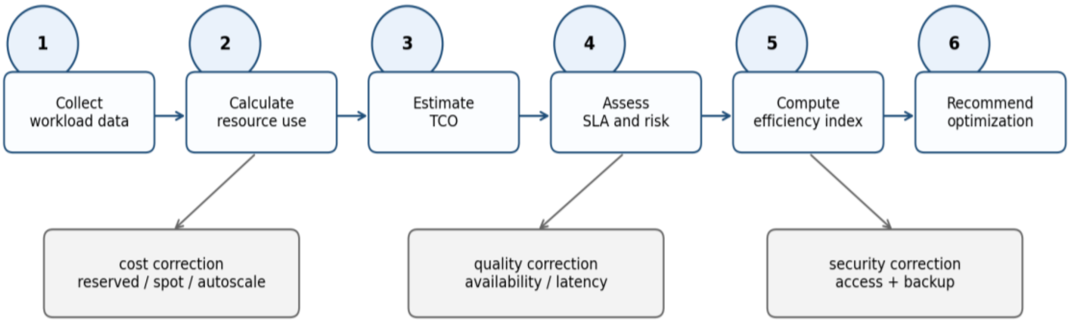

Figure 2. Algorithm for assessing and optimizing cloud computing efficiency.

The algorithm includes five main analytical blocks. The first block collects workload indicators such as number of users, transactions, storage growth, peak load and response time. The second block calculates allocated and actually used resources. The third block estimates direct and indirect costs. The fourth block evaluates service quality according to availability, latency, backup reliability and incident frequency. The fifth block converts all indicators into a normalized efficiency index and generates managerial recommendations.

For practical use, the algorithm can classify a cloud solution into three levels. If E_cloud is high and risk is low, the current architecture can be considered effective. If E_cloud is medium, the system requires optimization such as autoscaling, reserved capacity, data lifecycle management or service consolidation. If E_cloud is low, the organization should reconsider the deployment model, provider selection, architecture design or integration strategy.

5. Analytical Comparison of Cloud Deployment Models

Different cloud deployment models provide different efficiency effects. Public cloud is usually strong in elasticity and rapid deployment. Private cloud provides more control but requires more internal management. Hybrid cloud combines local and public resources, but integration complexity increases. On-premise infrastructure can be justified for specific security or legacy requirements, but it is less flexible for rapidly changing digital services.

Table 1. Comparative evaluation of infrastructure and cloud deployment approaches

Approach	Initial cost	Scalability	Management flexibility	Security control	Overall efficiency
On-premise infrastructure	High	Low	Medium	High	Medium
Private cloud	Medium-high	Medium	High	High	Medium-high
Public cloud	Low	High	High	Medium	High
Hybrid cloud	Medium	High	High	High	High

The comparison shows that there is no universal solution for all organizations. Public cloud is efficient for quickly growing digital platforms, online services, analytics workloads and experimental projects. Private cloud can be effective when the organization has strict data-control requirements and sufficient technical capacity. Hybrid cloud is often the most balanced model because it allows sensitive data to remain under stronger control while scalable workloads are placed in public cloud environments.

For digital economy development, the main advantage of cloud computing is not only cost reduction. Its strategic value is the acceleration of digital service creation. Organizations can test new applications faster, process large datasets, support remote users and integrate artificial intelligence services without building all infrastructure from the beginning. This creates an environment where innovation becomes less dependent on physical hardware procurement.

6. Practical Recommendations

The implementation of cloud technologies should begin with an inventory of existing information systems, data types, workload characteristics and security requirements. After that, systems should be grouped according to criticality. Non-critical and scalable services can be migrated first, while sensitive or legacy systems require additional analysis. This reduces migration risk and helps the organization gain practical experience before moving critical workloads.

Cost management is one of the most important conditions of cloud efficiency. Organizations should use resource tagging, monthly budget limits, automatic scaling, reserved instances for stable workloads and data lifecycle policies. Without these mechanisms, the cloud can become more expensive than local infrastructure. Therefore, cloud governance should include technical monitoring, financial monitoring and responsibility distribution between IT, finance and business units.

Security should be integrated into the architecture from the first stage. This includes multi-factor authentication, role-based access control, encryption, backup, incident monitoring and regular audit. Cloud security is a shared responsibility: the provider protects the infrastructure, but the customer remains responsible for correct configuration, access policy, data classification and user behavior. For this reason, employee training is also part of cloud efficiency.

7. Scientific Novelty and Practical Value

The scientific novelty of the article is the development of a multi-criteria approach to evaluating cloud computing efficiency in the digital economy. The proposed model combines economic, technical, organizational and security indicators into one analytical structure. This makes it possible to compare cloud alternatives not only by price, but also by service quality, scalability, risk and management value.

The practical value of the study is that the proposed model can be used by organizations planning cloud migration or evaluating the effectiveness of already implemented cloud services. It can support the preparation of digital transformation roadmaps, investment justification, IT budget planning and cloud optimization programs. The model is also useful for educational purposes because it explains cloud efficiency through measurable indicators and formulas.

8. Conclusion

This article analyzed the efficiency of cloud computing technologies in the context of the digital economy and proposed a multi-criteria evaluation model. The research shows that cloud computing should be evaluated through a combination of total cost, resource utilization, service availability, performance, scalability, security and risk. The proposed formulas and evaluation algorithm help convert these indicators into a unified efficiency index.

The analytical comparison indicates that hybrid cloud and public cloud approaches can provide high efficiency when they are supported by proper governance, security control and cost optimization. At the same time, cloud implementation must be adapted to organizational goals, workload characteristics and data protection requirements. Future research may include empirical testing of the model in enterprises and universities, development of a software prototype for automatic efficiency calculation and integration with cloud monitoring dashboards.

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