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A Strategic Framework For Modernizing Legacy Enterprise Applications Through Cloud-Based Migration Models

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ABSTRACT

The modernization of legacy enterprise applications has become a strategic priority for organizations seeking operational agility, scalability, resilience, and digital competitiveness. Traditional enterprise systems often suffer from technological rigidity, high maintenance costs, limited interoperability, and reduced adaptability to dynamic market conditions. Cloud computing has emerged as a transformative paradigm capable of addressing these limitations through elastic resource allocation, distributed architectures, virtualization, and service-oriented infrastructures. However, migration from legacy environments to cloud ecosystems involves substantial architectural, operational, security, governance, and financial challenges. This research develops a strategic framework for modernizing legacy enterprise applications through cloud-based migration models by integrating architectural transformation principles, migration methodologies, operational optimization mechanisms, and governance-oriented deployment strategies. The study synthesizes contemporary research on cloud migration frameworks, adaptive planning approaches, cloud-native architectures, security integration, and enterprise transformation models. A structured methodology is proposed that aligns migration readiness assessment, architectural decomposition, deployment selection, security governance, automation, and continuous optimization into a unified modernization framework. The paper further evaluates the implications of migration strategies such as rehosting, replatforming, refactoring, and cloud-native transformation in enterprise contexts. Findings indicate that successful modernization depends not only on technical migration mechanisms but also on organizational alignment, cost governance, DevOps integration, workload prioritization, and resilience engineering. The proposed framework contributes to research by establishing a multidimensional migration model capable of balancing scalability, security, operational continuity, and business value generation. The study concludes that strategic cloud migration enables sustainable enterprise modernization when supported by adaptive governance, architectural modularity, and continuous optimization practices.

Keywords: Cloud migration, legacy modernization, enterprise applications, cloud-native architecture, digital transformation, migration framework, DevOps integration, enterprise architecture, cloud optimization, application modernization

INTRODUCTION

Enterprise organizations increasingly rely on digital infrastructures to sustain operational continuity, improve customer engagement, and support data-driven decision-making. Many organizations continue to operate legacy applications developed using monolithic architectures, tightly coupled systems, and outdated

infrastructure environments. Although such systems historically supported organizational stability, they now present significant barriers to innovation, scalability, integration, and operational responsiveness. Legacy environments typically require high maintenance expenditure, prolonged deployment cycles, limited interoperability, and extensive dependency management, thereby reducing organizational adaptability in competitive digital ecosystems.

Cloud computing has emerged as a transformative technological paradigm capable of addressing these structural limitations through elastic infrastructure provisioning, virtualization, distributed computing, and service-oriented delivery mechanisms. According to M. Armbrust et al., cloud computing introduces scalable and utility-oriented computing environments capable of fundamentally reshaping enterprise information systems and operational efficiency (Armbrust et al., 2009). Cloud migration enables organizations to modernize application ecosystems by reducing infrastructure complexity, enabling flexible deployment models, and supporting continuous service delivery.

The growing importance of cloud-enabled modernization is also associated with the increasing need for business continuity, distributed operations, remote accessibility, and digital transformation. Enterprises are under pressure to modernize existing systems while maintaining uninterrupted operational functionality. However, cloud migration is not merely a technical relocation exercise. It involves architectural redesign, operational restructuring, security realignment, resource optimization, governance adaptation, and strategic transformation planning. Migration initiatives frequently encounter challenges related to data interoperability, application dependency mapping, security integration, workload prioritization, cost unpredictability, and organizational resistance.

Research studies have proposed multiple migration strategies including rehosting, replatforming, refactoring, rebuilding, and replacement models. These approaches differ significantly in terms of complexity, business value, risk exposure, and modernization outcomes. While rehosting offers rapid migration with minimal modification, refactoring and cloud-native redesign enable deeper modernization through microservices, elasticity, and distributed orchestration. Consequently, organizations require structured frameworks capable of selecting appropriate migration models based on technical readiness, operational objectives, and enterprise constraints.

The research problem addressed in this paper centers on the absence of integrated strategic frameworks that combine architectural modernization, migration governance, operational optimization, and security-oriented deployment into a unified enterprise modernization process. Existing literature often focuses on isolated technical mechanisms without adequately addressing enterprise-wide strategic alignment.

The primary objectives of this study are to:

1. Examine the theoretical and technical foundations of cloud-based legacy modernization.
2. Analyze existing migration models, architectural approaches, and operational strategies.
3. Develop a strategic framework for enterprise application modernization through cloud migration.
4. Evaluate the implications of migration methodologies on scalability, security, resilience, and operational agility.
5. Identify limitations, risks, and future directions in cloud-enabled modernization.

The scope of this research focuses on enterprise application modernization using public, private, hybrid, and multi-cloud environments. The study addresses migration planning, architectural transformation, cloud-native enablement, governance integration, security management, and operational optimization. The significance of this research lies in its contribution toward establishing a structured and scalable migration framework capable of supporting sustainable digital transformation initiatives.

2. Literature Review

Cloud computing research has evolved significantly from foundational infrastructure models toward enterprise-scale modernization strategies. Early studies emphasized the scalability and economic potential of distributed cloud infrastructures. Armbrust et al. (2009) presented one of the foundational analyses of cloud computing by explaining utility computing, elastic provisioning, virtualization, and distributed resource

management. Their work established cloud computing as an economically scalable paradigm capable of reducing infrastructure investment and enabling dynamic service delivery. The study further emphasized elasticity, resource pooling, and on-demand scalability as critical characteristics influencing enterprise transformation.

Greenberg et al. (2008) explored the economic dimensions of cloud computing by analyzing cost structures associated with cloud infrastructures. Their findings demonstrated that distributed cloud architectures significantly reduce operational expenditures while improving infrastructure utilization efficiency. Similarly, Kozhipurath (2012) investigated cloud service costing challenges and identified cost unpredictability, service measurement complexity, and billing transparency as major barriers to enterprise cloud adoption.

Migration-oriented research has proposed various strategies for transitioning legacy systems into cloud environments. Jamshidi, Ahmad, and Pahl (2013) conducted a systematic review of cloud migration research and categorized migration methodologies into architectural adaptation, deployment migration, operational transformation, and application reengineering. Their review highlighted the absence of standardized migration governance models capable of addressing organizational diversity.

Vu and Asal (2012) examined the practicability of legacy application migration and proposed methodological approaches for evaluating migration feasibility. Their study emphasized dependency mapping, workload prioritization, and infrastructure compatibility as critical migration determinants. Rai, Mehfuz, and Sahoo (2014) further analyzed migration efficiency by comparing migration strategies across scalability, interoperability, and deployment flexibility dimensions. Their work identified reusability and modularization as important characteristics for successful migration outcomes.

Architectural modernization has emerged as a major research domain within cloud migration literature. Mendonça (2014) discussed architectural options for cloud migration and identified rehosting, revision, rebuilding, and replacement as major modernization strategies. The study argued that migration success depends heavily on architectural decomposition and application modularity. Similarly, Nuthula and Challa (2014) investigated cloud-enabled application design considerations and emphasized interoperability, service abstraction, and deployment flexibility.

Tak and Tang (2014) proposed AppCloak, a rapid migration mechanism designed to simplify legacy application transformation into cloud environments. Their work demonstrated that virtualization-based abstraction can accelerate migration while minimizing direct modifications to application logic. Yu et al. (2011) introduced a practical cloudification architecture emphasizing service-oriented decomposition and workload abstraction. These studies collectively indicate that architectural transformation is central to sustainable modernization.

Research on cloud-native transformation further expanded modernization discourse beyond simple migration. Linthicum (2017) differentiated between conventional cloud migration and cloud-native application development by emphasizing microservices, containerization, orchestration, and distributed scalability. Fritzsch et al. (2019) examined monolithic-to-microservices refactoring approaches and identified decomposition complexity, service orchestration, and dependency isolation as major transformation challenges.

Security and resilience remain critical concerns in cloud migration research. Pfaff and Ries (2017) analyzed security integration pitfalls associated with cloud ecosystems and highlighted challenges related to identity management, policy enforcement, and multi-tenant isolation. Hsu et al. (2014) proposed MicroApp architectures for managing non-uniform trustworthiness in cloud applications. Their research emphasized layered trust management and modular security integration.

Survivability and resilience were explored by Zhani and Boutaba (2015), who focused on fault tolerance mechanisms in cloud environments. Their findings demonstrated that distributed redundancy, automated recovery, and workload balancing significantly improve service continuity. Similarly, Chou and Oetting (2022) examined secure system development practices for integrated cloud applications and highlighted the importance of secure development lifecycle integration.

Enterprise transformation and operational governance constitute another major research dimension. Yu and Madiraju (2014) proposed business-value-driven

transformation strategies emphasizing organizational alignment and IT supportability. Singh (2018) explored strategic enterprise operating models and argued that modernization initiatives require governance synchronization across technological and managerial domains.

DevOps and automation have increasingly influenced migration research. Offerman et al. (2022) analyzed DevOps adoption and concluded that automation, continuous integration, and collaborative workflows significantly improve deployment reliability and operational agility. Nabavi and Bushehrian (2019) proposed adaptive and continuous migration approaches suitable for dynamic enterprises, emphasizing incremental modernization rather than disruptive transformation.

Resource optimization and scalability also remain prominent research themes. Li, Zhang, and Sun (2019) proposed resource allocation algorithms for elastic enterprise migration, demonstrating the importance of workload balancing and adaptive provisioning in cloud performance optimization. Multi-tenancy frameworks investigated by Bhatia and Gupta (2016) further emphasized infrastructure efficiency and service scalability.

Despite substantial progress in cloud migration research, several gaps remain evident. First, many studies focus primarily on technical migration mechanisms without integrating governance, operational continuity, and strategic transformation considerations. Second, limited research provides unified frameworks combining architectural modernization, security governance, DevOps integration, and optimization strategies into a cohesive enterprise migration model. Third, migration decision-making remains fragmented due to varying organizational contexts and deployment complexities.

This study addresses these gaps by proposing a strategic framework that synthesizes migration planning, architectural transformation, governance integration, cloud-native enablement, security management, and operational optimization into a comprehensive modernization model.

3. Methodology

3.1 Research Design

This research adopts a conceptual and analytical methodology for developing a strategic framework for modernizing legacy enterprise applications through cloud-based migration models. The methodology is grounded in comparative synthesis of existing cloud migration literature, architectural modernization theories, enterprise transformation models, and operational governance practices. The research integrates theoretical constructs from cloud computing, enterprise architecture, migration engineering, and digital transformation domains.

The methodological structure consists of five interconnected stages: migration readiness assessment, migration model selection, architectural modernization, operational integration, and continuous optimization. Each stage incorporates technical, organizational, and governance-oriented dimensions to ensure holistic modernization.

3.2 Migration Readiness Assessment Framework

The first stage of the proposed framework focuses on assessing organizational and technical readiness for cloud migration. Legacy enterprise systems often contain tightly coupled dependencies, obsolete technologies, fragmented data structures, and undocumented operational workflows. Consequently, readiness assessment becomes essential for reducing migration risks.

The readiness assessment framework evaluates six major dimensions:

1. Infrastructure compatibility
2. Application modularity
3. Data portability
4. Security compliance requirements
5. Operational criticality
6. Organizational transformation readiness

Infrastructure compatibility determines whether existing systems can support virtualization, distributed deployment, and scalable orchestration. Highly dependent systems with proprietary hardware constraints may require partial redesign before migration.

Application modularity assessment examines the extent

to which applications can be decomposed into independent services or reusable components. Monolithic systems with tightly integrated logic present greater migration complexity compared to service-oriented architectures.

Data portability assessment evaluates schema compatibility, interoperability requirements, data governance constraints, and migration latency considerations. Enterprise systems containing heterogeneous data structures often require intermediate transformation layers.

Security compliance assessment addresses regulatory obligations, identity management, encryption requirements, access control policies, and auditability constraints. Sensitive enterprise applications operating within regulated industries require stronger governance-oriented migration planning.

Operational criticality assessment identifies applications requiring high availability, low latency, and uninterrupted service continuity. Critical workloads may necessitate phased or hybrid migration strategies.

Organizational readiness evaluation measures management support, workforce capability, process adaptability, and DevOps maturity. Transformation resistance frequently emerges as a non-technical barrier affecting migration outcomes.

3.3 Cloud Migration Strategy Classification

The proposed framework classifies migration strategies into five primary categories.

3.3.1 Rehosting Strategy

Rehosting, commonly known as lift-and-shift migration, involves transferring applications into cloud infrastructure with minimal modification. This strategy enables rapid migration and lower initial transformation costs. Rehosting is appropriate for stable applications requiring immediate infrastructure modernization.

However, rehosting offers limited modernization benefits because legacy architectural limitations remain unchanged. Scalability constraints, monolithic dependencies, and inefficient resource utilization may continue after migration.

3.3.2 Replatforming Strategy

Replatforming introduces moderate modifications to improve cloud compatibility without fundamentally redesigning applications. According to migration models discussed in cloud migration strategies literature, replatforming enables enterprises to optimize databases, middleware, and runtime environments while maintaining core application structures.

This strategy balances modernization and operational continuity. It improves scalability and deployment flexibility while minimizing redevelopment complexity.

3.3.3 Refactoring Strategy

Refactoring involves substantial architectural redesign to align applications with cloud-native principles. Monolithic applications are decomposed into microservices supported by containers, orchestration engines, and distributed APIs.

Refactoring provides high scalability, resilience, and deployment agility. However, it requires significant development investment, dependency analysis, and organizational capability transformation.

3.3.4 Rebuilding Strategy

Rebuilding replaces existing applications with newly developed cloud-native systems. This strategy is suitable when legacy systems are technologically obsolete or operationally unsustainable.

Although rebuilding offers maximum modernization flexibility, it introduces higher implementation cost and longer deployment timelines.

3.3.5 Hybrid Migration Strategy

Hybrid migration combines multiple approaches based on workload characteristics and organizational priorities. Critical applications may undergo incremental refactoring while non-critical systems are rehosted.

Hybrid strategies are increasingly relevant in large enterprises because they enable gradual modernization while reducing transformation disruption.

3.4 Architectural Modernization Model

Architectural modernization constitutes the core technical dimension of the proposed framework. Traditional enterprise systems often rely on monolithic

architectures that reduce scalability, deployment agility, and fault isolation capabilities.

The proposed modernization model integrates the following architectural principles:

3.4.1 Service Decomposition

Applications are decomposed into modular services aligned with functional domains. Service decomposition improves scalability, fault isolation, and deployment independence.

Microservices architectures enable distributed scaling and independent lifecycle management. According to Fritzsch et al. (2019), service decomposition significantly improves operational agility in complex enterprise systems.

3.4.2 Containerization and Orchestration

Containerization technologies encapsulate application components into portable execution environments. Containers reduce infrastructure dependency and improve deployment consistency.

Orchestration frameworks automate deployment, scaling, monitoring, and recovery operations. Automated orchestration enhances resilience and operational efficiency.

3.4.3 API-Centric Integration

Modernized enterprise systems require API-driven interoperability for integrating distributed services, external platforms, and hybrid infrastructures. API-centric architectures improve communication flexibility and reduce integration complexity.

3.4.4 Elastic Resource Provisioning

Elastic provisioning enables dynamic allocation of computational resources according to workload demand. Cloud infrastructures support automatic scaling mechanisms capable of optimizing resource utilization.

Armbrust et al. (2009) identified elasticity as a foundational cloud computing capability influencing scalability and economic efficiency.

3.4.5 Multi-Tenant Optimization

Multi-tenant architectures improve infrastructure efficiency by enabling shared resource utilization across multiple services or organizational units. Bhatia and Gupta (2016) demonstrated that multi-tenant frameworks significantly improve scalability and infrastructure optimization.

3.5 Security and Governance Integration

Security integration represents a critical requirement for enterprise cloud modernization. Migration introduces risks associated with distributed infrastructures, third-party dependencies, data exposure, and identity fragmentation.

The proposed framework integrates security across all modernization stages.

3.5.1 Identity and Access Management

Centralized identity governance ensures consistent authentication, authorization, and policy enforcement across distributed cloud services.

Role-based access control and zero-trust architectures improve operational security.

3.5.2 Encryption and Data Protection

Data encryption mechanisms protect enterprise information during storage, transmission, and processing.

Encryption integration becomes particularly important in hybrid and multi-cloud environments.

3.5.3 Continuous Security Monitoring

Continuous monitoring frameworks detect anomalies, vulnerabilities, and unauthorized activities in real time.

Automated threat detection improves resilience and reduces incident response latency.

3.5.4 Compliance Governance

Enterprises operating in regulated sectors require policy-driven governance mechanisms ensuring regulatory alignment.

Compliance-oriented governance includes audit logging, policy validation, and access traceability.

3.6 DevOps and Continuous Modernization

Modern enterprise transformation increasingly depends on DevOps integration and continuous deployment mechanisms. Traditional deployment approaches are insufficient for dynamic cloud ecosystems requiring rapid iteration and scalable deployment.

The proposed framework incorporates DevOps practices including:

1. Continuous integration
2. Continuous deployment
3. Infrastructure as code
4. Automated testing
5. Configuration management
6. Performance monitoring

Offerman et al. (2022) demonstrated that DevOps adoption improves deployment reliability, collaboration efficiency, and operational agility.

Continuous modernization enables enterprises to iteratively optimize cloud architectures rather than relying on static transformation models.

3.7 Operational Optimization Model

Operational optimization focuses on maximizing performance, cost efficiency, and resilience after migration.

3.7.1 Resource Allocation Optimization

Elastic workload balancing enables efficient computational distribution across cloud resources.

Li, Zhang, and Sun (2019) proposed optimization models demonstrating that adaptive provisioning significantly improves enterprise application performance.

3.7.2 Fault Tolerance Engineering

Fault tolerance mechanisms ensure operational continuity despite infrastructure failures.

Zhani and Boutaba (2015) emphasized redundancy and automated recovery as essential resilience mechanisms.

3.7.3 Cost Governance

Cloud environments may generate unpredictable expenditure due to elastic consumption models. Cost governance frameworks monitor resource utilization and optimize operational expenditure.

3.7.4 Performance Analytics

Performance monitoring systems evaluate workload efficiency, latency patterns, infrastructure utilization, and scalability performance.

Analytics-driven optimization improves long-term operational sustainability.

3.8 Proposed Strategic Framework

The proposed strategic framework integrates all modernization dimensions into a unified migration lifecycle consisting of:

1. Readiness assessment
2. Workload classification
3. Migration strategy selection
4. Architectural decomposition
5. Security integration
6. DevOps enablement
7. Operational optimization
8. Continuous modernization

The framework emphasizes iterative transformation rather than one-time migration. This adaptive structure enables enterprises to continuously optimize systems according to evolving business requirements and technological developments.

4. Results / Findings

The analytical evaluation of existing cloud migration models and enterprise modernization strategies demonstrates that successful migration outcomes depend on multidimensional alignment between technical transformation, governance integration, operational continuity, and organizational adaptability. The proposed framework revealed that migration strategies cannot be universally applied because enterprise systems vary significantly in terms of architectural complexity, dependency structures,

compliance requirements, and operational criticality.

The findings indicate that rehosting strategies provide rapid infrastructure modernization with lower implementation complexity; however, they offer limited long-term scalability benefits due to the preservation of legacy architectural constraints. Replatforming strategies improve cloud compatibility and operational flexibility while maintaining moderate migration risk. Refactoring and cloud-native transformation approaches generate the highest scalability, agility, and resilience benefits but require substantial investment in architectural redesign, workforce capability development, and operational restructuring.

The research further demonstrates that enterprises adopting modular architectures, API-centric integration, and containerized deployment environments achieve significantly greater scalability and deployment agility compared to organizations relying on monolithic migration patterns. Microservices-based modernization enables fault isolation, workload distribution, and continuous deployment capabilities, thereby improving operational resilience.

Security-oriented findings emphasize that migration success is strongly associated with governance integration. Organizations implementing centralized identity management, continuous monitoring, encryption-based protection, and compliance-oriented policy frameworks experience lower operational risk and improved trustworthiness in distributed cloud environments. Security integration must therefore be treated as a foundational modernization component rather than a secondary operational activity.

The study also identified DevOps integration as a critical enabler of continuous modernization. Enterprises adopting automation-oriented deployment pipelines, infrastructure-as-code methodologies, and continuous integration frameworks demonstrated improved deployment reliability, reduced operational latency, and enhanced scalability performance.

Another important finding concerns cost governance and resource optimization. Although cloud infrastructures improve scalability and infrastructure flexibility, uncontrolled resource provisioning may increase operational expenditure. Organizations implementing adaptive resource allocation and performance analytics achieved more sustainable cloud operational models.

Finally, the findings confirm that enterprise modernization should be treated as a continuous transformation lifecycle rather than a one-time migration event. Incremental modernization strategies supported by adaptive governance and operational analytics generate more sustainable transformation outcomes.

5. Discussion

The findings of this research reinforce the argument that cloud migration represents a strategic enterprise transformation process rather than a purely technological infrastructure transition. Existing studies have frequently concentrated on migration methodologies or deployment mechanisms independently; however, this study demonstrates that successful modernization depends on synchronized interaction between architectural redesign, governance integration, operational optimization, and organizational capability transformation.

The proposed framework extends the foundational cloud computing principles identified by Armbrust et al. (2009) by integrating elasticity, scalability, and distributed resource management into enterprise modernization governance. While early cloud research emphasized infrastructure economics and computational scalability, contemporary enterprise transformation requires broader integration involving DevOps automation, security governance, workload orchestration, and business alignment.

The comparative analysis of migration models reveals important trade-offs. Rehosting enables rapid migration with minimal disruption, making it suitable for organizations requiring immediate infrastructure modernization. However, the approach frequently preserves architectural inefficiencies, thereby limiting long-term innovation potential. Conversely, refactoring and rebuilding strategies maximize cloud-native benefits but introduce greater implementation complexity and operational risk.

The study also supports the growing relevance of microservices and distributed architectures within enterprise modernization. The transition from monolithic systems toward modular cloud-native ecosystems improves scalability, fault tolerance, and deployment independence. Nevertheless, decomposition complexity, orchestration overhead, and service governance challenges remain significant

limitations requiring advanced operational capabilities.

Security integration emerged as one of the most critical modernization determinants. The distributed nature of cloud ecosystems increases exposure to identity fragmentation, policy inconsistency, and multi-tenant vulnerabilities. Consequently, governance-oriented security frameworks become essential for maintaining enterprise trustworthiness and compliance alignment.

The discussion further highlights the importance of continuous modernization models. Traditional migration frameworks often assume static transformation endpoints; however, dynamic enterprise environments require ongoing optimization and iterative adaptation. DevOps integration, automation, and continuous monitoring therefore represent essential components of sustainable cloud modernization.

Several limitations remain within the proposed framework. First, the research is conceptual and analytical rather than empirically validated through large-scale industrial implementation. Second, cloud migration complexity varies significantly across industries, limiting universal standardization. Third, emerging technologies such as edge computing, AI-driven orchestration, and serverless architectures may further alter modernization strategies in the future.

Despite these limitations, the proposed framework contributes theoretically and practically by establishing an integrated migration model capable of balancing operational continuity, scalability, security, and enterprise agility.

6. Conclusion

This research examined the strategic modernization of legacy enterprise applications through cloud-based migration models and developed a comprehensive framework integrating migration readiness assessment, architectural transformation, security governance, DevOps enablement, and operational optimization. The study demonstrated that enterprise modernization requires multidimensional alignment across technical, organizational, and governance-oriented domains.

The research identified that migration strategies such as rehosting, replatforming, refactoring, rebuilding, and hybrid transformation differ substantially in terms of scalability potential, implementation complexity, operational continuity, and modernization outcomes. Organizations selecting migration approaches without considering workload characteristics, governance requirements, and architectural readiness may experience limited transformation effectiveness.

The proposed framework contributes to cloud migration research by establishing a structured modernization lifecycle emphasizing iterative transformation, adaptive governance, and continuous optimization. The framework highlights the importance of modular architectures, containerized deployment, API-centric integration, fault tolerance engineering, and DevOps automation in achieving scalable and resilient enterprise ecosystems.

The findings further demonstrate that security integration, compliance governance, and cost optimization must be embedded throughout the migration lifecycle rather than treated as post-deployment considerations. Enterprises implementing continuous monitoring, identity governance, and analytics-driven optimization achieve more sustainable operational outcomes.

The study concludes that cloud-based modernization enables organizations to improve scalability, resilience, operational agility, and digital competitiveness when supported by strategic planning, architectural decomposition, and adaptive operational governance. Future research should focus on empirical validation of integrated migration frameworks, AI-driven orchestration models, and industry-specific modernization strategies.

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