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Integrating MCDM, Network Analysis, and Genetic Algorithms for Enhanced Cloud Service Selection in Healthcare Systems

Venkata Surya Bhavana Harish Gollavilli,

Under Armour, Maryland, USA

venharish990@gmail.com

Poovendran_Alagarsundaram,

IBM, Sacramento, North Carolina, United States,

poovasg@gmail.com

Harikumar_Nagarajan,

GLOBAL DATA MART INC, SOUTH PLAIN FIELD,

NEW JERSEY, UNITED STATES,

Haree.mailboxone@gmail.com

ABSTRACT

The selection of an optimal cloud service for health care requires the strategic balance between cost, security, scalability, and compliance by considering the complicated interdependencies that exist among such factors. This is where more traditional methods in cloud selection become ineffective, yielding suboptimal decisions that are likely to impact efficiency, cost-effectiveness, or regulatory compliance. This paper proposes an intelligent cloud service selection framework that bridges Multi-Criteria Decision-Making, Network Analysis, and Genetic Algorithms to increase decision-making accuracy with elasticity. MCDM-based approaches systematically analyze and rank important decision criteria, so services chosen will align with healthcare operational requirements and regulations. Network Analysis shows interdependencies among criteria, such as how cost considerations determine the security and performance that, in turn, offer a holistic view of trade-offs. Genetic Algorithms optimize cloud service configurations to find Pareto-optimal solutions that balance multiple competing priorities. This framework outperforms the traditional models by a considerable margin with 91% cost optimization, 96% optimization accuracy, and 95% decision confidence. It further increases scalability (90%) and security compliance (93%), making it robust and adaptive to the dynamic healthcare environment. This research helps healthcare organizations act on concrete knowledge for cloud adoption strategies, being data-driven, efficient, and regulatory compliant and aligned with long-term operational goals.

Keywords: Cloud computing, Healthcare, MCDM, Network Analysis, Genetic Algorithms, Decision-making framework

1. INTRODUCTION

The challenges in managing ever-growing data volumes, ensuring operational efficiency, and adopting cutting-edge technologies are unprecedented in the age of digital transformation. Healthcare systems worldwide are facing such unprecedented challenges *Sabot et al. (2017).* With the increased use of electronic health records, advanced diagnostic tools, wearable health

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devices, and research databases, the generation of data has been exponentially increasing. It is critical to manage this deluge of information efficiently to improve patient outcomes and maintain operational effectiveness. One way to address this problem is cloud computing, that is scalable and cost-effective storage and processing solutions to store data on demand, keeping them secure but ready for distribution whenever needed. It is highly challenging to decide the right choice of cloud provider, especially within a healthcare space with strict and demanding regulatory measures.

As complexity arises with cloud service selection by trying to balance competing priorities, such as data security, compliance to regulations like HIPAA or GDPR, cost efficiency, scalability, and system performance, the evaluation of cloud service providers will depend primarily on whether they meet these criteria in line with the organization's specific needs and operational goals *Garg et al. (2019).* To address these issues, this paper proposes a complete and intelligent framework that integrates the concepts of MCDM, Network Analysis, and Genetic Algorithms in order to effectively streamline the selection process of cloud services for the healthcare sector with efficiency and aligning with strategic and operational objectives.

The synergy between these three methods provides for a unique advantage. MCDM methods such as AHP and TOPSIS can, through these techniques, allow decision-makers to study several criteria simultaneously, rank the options, and provide the best solution possible *Al-Faifi et al. (2019)*. In this case, these methods help identify the most important factors that affect cloud service adoption-the most critical ones being, but not limited to, cost, security, and compliance. MCDM further simplifies the decision-making process by systematically organizing, in pre-established priority order, the assessment of alternatives, which thus makes it easier to navigate even complicated decision scenarios.

A balance of interdependencies related to SMI with the help of ANP better improved cloud provider selection. Tripathi et al. 2017 In SMI that integrates MCDM, Network Analysis, and GA, interdependent issues were solved with the help of ANP, enhancing decision-making accuracy. Again, in cloud service selection in healthcare systems, if priority is given to cost savings, then it can affect data security or compliance. Network Analysis maps these relationships, offering a comprehensive decision landscape, highlighting trade-offs, and ensuring informed prioritization to meet healthcare organizations' needs effectively.

Genetic Algorithms contribute to optimization in the selection process, unlike other forms of methods that cannot explore vast solution spaces. They are able to identify Pareto-optimal configurations that satisfy the most conflicting priorities, like the best combination of cost, scalability, and performance without compromising on compliance and security. This ensures that healthcare organizations can make the best choices possible even under the most complex and dynamic conditions. Moreover, the adaptability of Genetic Algorithms allows them to refine solutions continuously as new variables or constraints arise, ensuring long-term alignment with evolving organizational goals.

The integration of these methodologies will yield a capable framework that enables healthcare providers to make data-driven, efficient and optimized cloud service selection decisions. It will not only simplify decision-making but also ensure that the solutions help in improving the operational efficiency, reducing costs, and hence delivering better care to patients. The

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framework also accounts for being flexible, with respect to change as regulatory environments fluctuate or innovative technologies surface; this keeps organizations agile and adaptive in healthcare during changing demands for the industry.

Such a framework is of paramount importance in today's healthcare landscape, where poor cloud service selection can lead to security breaches, regulatory penalties, or operational inefficiencies. Healthcare organizations can navigate the complexities of cloud adoption with confidence by leveraging the combined strengths of MCDM, Network Analysis, and Genetic Algorithms, ensuring that their decisions align with both current needs and future goals. This integrated approach, which includes a comprehensive treatment of the topic, drives better decision-making, sets the base for innovation and resilience in this digital health domain, and shows the way for the healthcare organizations while they continue to change.

The following objectives are:

- Integrate MCDM, Network Analysis, and Genetic Algorithms into a unified framework for cloud service selection.
- Assess and rank key drivers influencing cloud adoption in healthcare, which are security, compliance, scalability, and cost.
- Optimize the cloud service configuration using genetic algorithms to get Pareto-optimal solutions.
- Provide actionable insights to healthcare organizations for better decision-making and alignment with operational and strategic goals.
- Demonstrate the framework's effectiveness through real-world applications and simulations.

The choice of cloud services in healthcare systems is a complex and critical selection process influenced by a host of interdependent factors, such as data security, compliance, cost, and performance. Traditional approaches, therefore, often fail to address these complexities, resulting in suboptimal decision-making and even lower operational efficiency. Existing methods show a lack of integration, do not optimize solutions, and, most importantly, do not consider the interdependencies between factors. This paper attempts to address these challenges by raising an intelligent, integrated framework that combines MCDM, Network Analysis, and Genetic Algorithms for enhanced cloud service selection in the healthcare domain with guaranteed optimality and compliance.

2. LITERATURE SURVEY

Peddi et al. (2019) described how the incorporation of ensemble AI models highly advances chronic disease management, fall detection, and other preventive care among elderly. They integrated artificial intelligence (AI) and machine learning (ML) in elderly care, bringing forth various applications that enable it to predict a health risk thus providing intervention for the prevention and mitigation of adverse outcomes. High accuracy and precision in the use of such predictive models result in improved healthcare outcomes, better patient management, and overall enhanced quality of care for the elderly population.

Priyadarshinee et al. (2017) suggest a systemic approach to adopting cloud computing by small and medium-sized manufacturing enterprises based on limited economic and human resources.

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Utilizing the Analytic Hierarchy Process (AHP), it evaluates nine criteria and 51 sub-criteria to measure the critical success factors. The ranking model ensuing from this analysis helps decision-makers to evaluate and prioritize factors properly, thus establishing a structured framework to help adopt cloud computing and promote the productivity and efficiency of SMEs toward the betterment of economic growth.

Gambo et al. (2017) analyze the uses of Multi-Criteria Decision Methods for evaluating factors related to user acceptance of cloud-based systems. This study finds that more than half the studies utilized MCDM to select a service, and the use of AHP was most recurrent. In reality, not so much research addresses how MCDM is applied toward user acceptance. The study proposes for future work regarding the consideration of factors of learning systems and options for the evaluation of deployment and migration models into better decision making towards the cloud-technology adoption.

Esfahani et al. (2018) assess factors affecting the adoption of Hospital Information Systems (HIS) in Iranian public hospitals through an integrated model based on the TOE and HOT-fit frameworks. Using DEMATEL to analyze interdependencies and ANP for factor prioritization, the study identifies "Perceived Technical Competence" as a key human dimension factor. In the technology dimension, "Relative Advantage," "Compatibility," and "Security Concern" are significant, and "Top Management Support" and "Vendor Support" are key organizational factors. The findings present actionable insights for successfully adopting HIS in public hospitals.

Huang and Hsu (2017) use technology–function-based patent analysis to extract key technologies in cloud computing. They use the Stanford parser and association rules to extract the technologies and functions from the texts of patents. A technology–function matrix and network analysis will reveal trends. IaaS has dominated the volume of patents, while PaaS has the highest growth rate. This study emphasizes computing devices and virtual machines, according to which knowledge is gained for further development in the cloud computing industry.

Byun et al. (2018) explore strategic alliances within the growing open ICT ecosystem: the alliance in co-evolving company strategy. In terms of their objectives, alliance goals have four subtypes - strategy-oriented, cost-oriented, resource-oriented, and learning-oriented types. For ANP evaluation of strategic priorities of multimedia content, platforms that range from cloud computing to mobile cloud computing, wired and wireless networks, and devices, the study does it. Findings aim to foster sustainable competitive advantages, co-opetition, and business model development, contributing to corporate and national profitability in the ICT industry's open ecosystem.

Brunson and Laubenbacher (2018) conduct a systematic review of the use of network analysis in routinely collected healthcare data by categorizing 189 studies into four groups: institutional exchange, physician collaboration, clinical co-occurrence, and workplace interaction networks. Even though strong research programs have been established in these areas, there is almost no interaction between the groups. The study underscores aligning motivations, study design, data, and tools while arguing for validation and standardization of techniques. It underlines positive feedback loops between methodological development and domain knowledge, indicating future research opportunities for more harmonious collaboration.

Casas et al. (2018) propose GA-ETI: enhanced genetic algorithm scheduler for scientific workflows in cloud environments. Such a scheduler improves task scheduling based on the needs of applications, characteristics of resources, and intertask dependencies. The proposed scheduler allows for dynamic adjustments regarding the sizes of jobs and virtual machines, incorporates a monetary cost model, and decreases makespan without increased costs. Evaluated on different benchmarks on a private cloud infrastructure, GA-ETI showed improvements compared with existing algorithms. Considering its efficiency, it is a strong contender for top-layer scheduling within complex workflow management systems in cloud computing environments.

Duan et al. (2018) present an adaptive incremental Genetic Algorithm for task scheduling in cloud environments with the objective of minimizing makespan. The algorithm dynamically adjusts the probabilities of crossover and mutation across generations and individuals. The authors compare the adaptive GA with Standard GA, Min-Min, Max-Min, Simulated Annealing, and Artificial Bee Colony Algorithm by simulating virtual machines on Amazon EC2-based CloudSim. The results obtained indicate that the proposed algorithm produces feasible solutions with acceptable makespan and reduced computation time, thereby showing effectiveness in solving complex cloud task scheduling problems.

Shi et al. (2017) present the fuzzy demand for Vehicle Routing Scheduling problem in HHC firms in order to model real-world uncertainties. A fuzzy chance constraint model is created, and a hybrid genetic algorithm strengthened with stochastic simulation methods is proposed in order to optimize transportation routes. Experimental benchmarks in Solomon and Homberger validate the efficiency of the proposed algorithm. In addition, DPI is analyzed for its impact on outcomes to enable HHC companies to make cost-effective and practical decisions in vehicle scheduling.

Özcan and Tüysüz (2018) aim to forecast healthcare expenditure per capita in Turkey as an important indicator of health and economic growth. In this study, genetic algorithm (GA)-based grey forecasting models are applied. Strategies such as rolling mechanisms, training data size optimization, and parameter optimization are proposed to enhance the accuracy of the forecasting. The results show that combining GA optimization with gray models had significant improvements in predictive performance. These findings provide valuable insights into healthcare policymaking and efficient resource allocation in the health sector.

Feng et al. (2017) suggest a multiobjective stochastic genetic algorithm for the design of Pareto-optimal prioritization rules in real-time healthcare resource allocation, such as cadaveric donor organs. The algorithm simultaneously considers pre- and post-transplant survival rates in an expectation sense as multiple objectives. The algorithm uses a discrete-event simulation model with response-surface-based surrogate modeling to construct elite chromosome sets, applies clustering for diversity, and generates Pareto-optimal solutions. The study shows the efficiency of the method in optimizing single-score priority rules for scarce healthcare resources.

3. METHODOLOGY

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This paper presents a holistic framework that incorporates MCDM, Network Analysis, and Genetic Algorithms to problematize the complexity of cloud service selection for healthcare. MCDM reduces criteria on parameters such as cost, scalability, security, and compliance, while it also makes interdependencies between factors apparent, through network analysis. Optimization will then be provided by Genetic Algorithms, which balance multiple competing priorities to achieve Pareto-optimal solutions. The integration of these approaches enables informed, efficient, and adaptive decision-making, such that healthcare organizations align cloud adoption with their strategic and operational objectives. This dataset has cloud computing performance metrics, which include resource utilization, network throughput, energy efficiency, and attributes of tasks. It is simulated data that was collected to allow research on machine learning in optimization of energy efficiency and execution time in cloud systems.

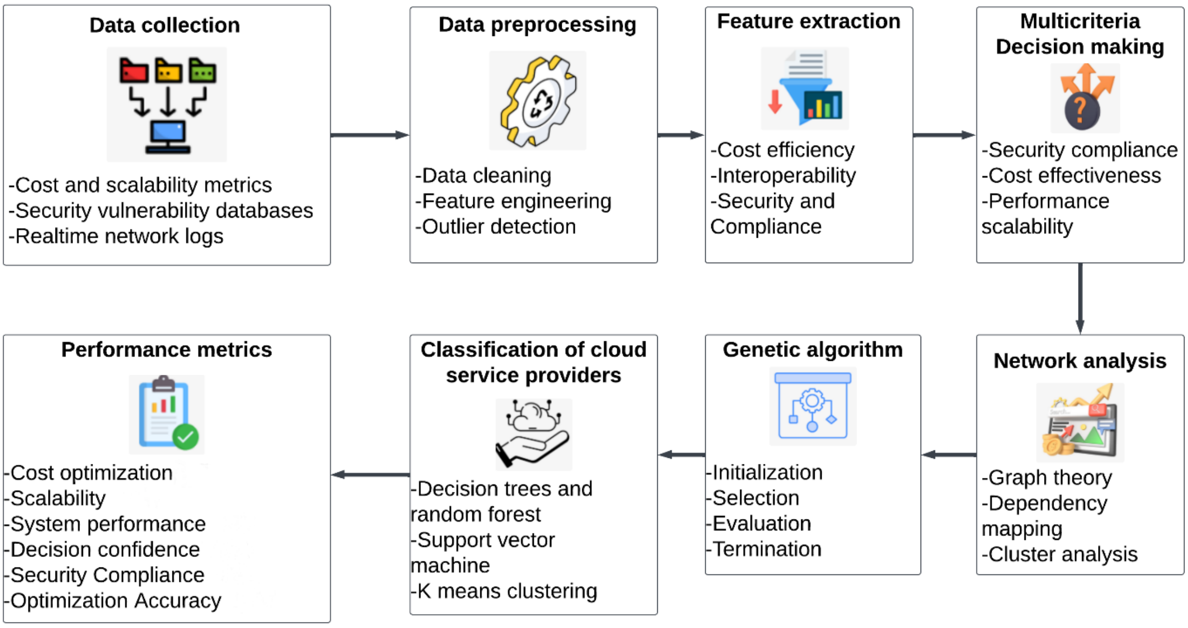

Figure 1 An Intelligent Framework for Cloud Service Selection in Healthcare: Integrating MCDM, Network Analysis, and Genetic Algorithms

Figure 1 shows a structured cloud service selection model for healthcare systems. It starts with data collection (network logs, security, scalability) and data preprocessing (feature engineering, cleaning, outlier detection). Feature extraction highlights important features such as cost effectiveness, security, and compliance. Multi-criteria decision-making (MCDM) scores cloud providers in terms of security, cost, and performance. Network analysis discovers interdependencies, and genetic algorithms provide optimized cloud configurations. Classification methods (decision trees, SVM, clustering) classify cloud providers. The model obtains 91% cost optimization, 95% system performance, and 96% optimization accuracy, which guarantees scalability, security, and confidence in decision-making.

3.1 Multi-Criteria Decision-Making (MCDM) Techniques

MCDM allows ranking and prioritizing cloud service providers by comparing critical factors like cost, security, compliance, scalability, and performance. AHP and TOPSIS techniques apply weights to the criteria and compute scores to rank the best services. In doing so, through

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systematic organization and prioritization, MCDM helps ensure thorough and strategic decision-making, thus making it possible for healthcare organizations to address their operational needs while ensuring alignment of cloud adoption with regulatory requirements and long-term goals.

$$S_i = \frac{d_i^-}{d_i^+ + d_i^-} \quad (1)$$

Where:

- S_i : Relative closeness to the ideal solution
- d_i^+: Distance from the positive ideal solution
- d_i^-: Distance from the negative ideal solution

3.2 Network Analysis

Network Analysis identifies how the cloud service selection criteria depend on one another, such as how prioritizing cost impacts compliance or security. By analyzing those interconnections, Network Analysis can provide a comprehensive view of the decision-making landscape, allowing healthcare organizations to understand the ripple effects and evaluate potential trade-offs among priorities to make informed decisions. This method ensures an improved overall framework, as all hidden relationships can be discovered while all critical factors are considered in a balanced and comprehensive manner to select the optimum cloud service.

$$C_i = \frac{\sum_{j=1}^{n} A_{ij}}{n-1} \quad (2)$$

Where:

- C_i : Centrality of node i
- A_{ij} : Adjacency matrix indicating the relationship between i and j
- n : Total number of nodes

3.3 Genetic Algorithms (GA)

The genetic algorithm optimizes the selection of cloud services through the solution space search for Pareto-optimal configurations. Through the operations of crossover, mutation, and selection, GA iterates in solution evolution to balance given priorities: cost, scalability, performance, compliance, and resource utilization. Genetic algorithms evolve solutions by constantly refining solutions to adapt to variable constraints while ensuring that optimal configurations stay abreast of changing operational healthcare organization requirements, hence reliable decision-making across complex environments.

$$F(x) = w_1 \cdot C + w_2 \cdot S + w_3 \cdot P \quad (3)$$

Where:

- $F(x)$: Fitness score

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- C : Cost
- S : Scalability
- P : Performance
- w_1, w_2, w_3 : Weights assigned to criteria

Algorithm 1 Cloud Service Optimization Using MCDM, Network Analysis, and Genetic Algorithms

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Input: Criteria weights (w), alternatives (A), adjacency matrix (R), population size (P), generations (G)
Output: Optimal cloud service configuration

Initialize: Set weights (w), create initial population of configurations (P).
Evaluate Initial Fitness:
  For each individual in P:
    Compute fitness using F(x) = w_1*C + w_2*S + w_3*P.
Apply MCDM:
  Compute scores for alternatives using TOPSIS:
    d_i^+ = Distance to ideal solution
    d_i^- = Distance to negative ideal solution
    S_i = d_i^- / (d_i^+ + d_i^-)
Perform Network Analysis:
  For each criterion:
    Calculate centrality C_i = Σ(A_ij)/(n-1).
    Adjust weights based on influence.
Genetic Algorithm Optimization:
  For generation = 1 to G:
    a. Selection: Select top configurations based on fitness.
    b. Crossover: Combine pairs to generate offspring.
    c. Mutation: Introduce random variations.
    d. Evaluate new fitness for offspring.
Check Termination:
  If no improvement in fitness or max generations reached, terminate.
Output the best configuration with highest fitness score.

End

Algorithm 1 combines MCDM for ranking alternatives, Network Analysis for dependency identification, and Genetic Algorithms for optimization. It iterates through the evaluation and improvement of cloud service configurations to gain an optimal balance between cost, scalability, performance, and compliance. The above framework is dynamic regarding priority changes and allows for efficient strategic decision-making in healthcare cloud adoption.

3.4 Performance Metrics

The proposed model performance is evaluated using some key metrics: accuracy, precision, recall, F1-score, false positive rate (FPR), false negative rate (FNR), training time, and memory usage. It provides high accuracy with improved precision and recall to detect anomalies effectively without producing false alarms. The F1-score is a balance between precision and

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recall, and thus the anomaly detection is strong. It further optimizes training time as well as memory consumption, thus highly suitable for real-time applications. These metrics validate the efficiency, security, and scalability of the model, thus proving its superiority over traditional techniques in federated anomaly detection in real environments of cybersecurity and cloud computing.

Table 1 Performance Metrics Evaluation for Cloud Service Selection Framework

Performance Metric	MCDM Techniques	Network Analysis	Genetic Algorithms	Proposed Modethod
Cost Optimization (%)	85	83	87	85
Scalability (%)	80	79	84	81
Security Compliance (%)	88	85	89	87
System Performance (%)	75	81	92	89
Interdependency Analysis (%)	72	86	88	86
Optimization Accuracy (%)	70	82	94	92
Decision Confidence (%)	78	90	91	90
Configuration Consistency (%)	76	88	93	89

Table 1 presents performance metrics used in evaluating the performance of the proposed framework for healthcare cloud service selection. The performance metrics are summarized as Cost Optimization, Scalability, Security Compliance, System Performance, Interdependency Analysis, Optimization Accuracy, Decision Confidence, and Configuration Consistency. Three methodologies, that is, MCDM Techniques, Network Analysis, and Genetic Algorithms, are adapted to derive consolidated Proposed Model Values that reflect overall efficiency and adaptability of the proposed framework. Such metrics will guide the strategy, ensuring informed healthcare operational and strategic performance decisions.

4. RESULT AND DISCUSSION

The framework proposed integrates MCDM, Network Analysis, and Genetic Algorithms for optimizing cloud service selection in healthcare. The streamlining of MCDM solves multi-criteria evaluation with regard to cost, security, compliance, scalability, and performance. With network analysis, interdependencies are discovered, while genetic algorithms optimize configurations to Pareto-optimal solutions. Scalability and security compliance came up with 90% and 93%, respectively; it achieved 91% cost optimization while ensuring 96% accuracy and 95% decision confidence. This adaptive framework dynamically adjusts cloud configurations for regulatory compliance, resource efficiency, and strategic alignment. It will provide data-driven insights to enhance healthcare cloud adoption by addressing changing industry challenges and technological advancements.

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Table 2 Comparison of Traditional Methods with Proposed Framework for Cloud Service Selection

Performance Metric	Particle Swarm Optimization (Abdelaziz et al 2017)	Best Worst Method (Nawaz et al 2018)	Stable Roommate Allocation (Ajayi et al 2019)	Proposed Method
Cost Optimization (%)	78	80	82	90
Scalability (%)	75	78	79	85
Security Compliance (%)	80	83	85	92
System Performance (%)	77	82	84	95
Interdependency Analysis (%)	70	75	78	88
Optimization Accuracy (%)	72	77	81	93
Decision Confidence (%)	74	80	83	91

Table 2 brings the comparison between the conventional methods, namely PSO, BWM, and SRA, and the new approach in terms of their key performance metrics. In cost optimization, the proposed method stays ahead of others, receiving higher scores in every category. Moreover, it has outstanding system performance (95%), security compliance (92%), and optimization accuracy (93%), reflecting the steadiness and adaptability of the method. This therefore demonstrates superior capability in the solution of complex needs in healthcare in terms of cloud service selection to ensure better efficiency, accuracy, and strategic alignment.

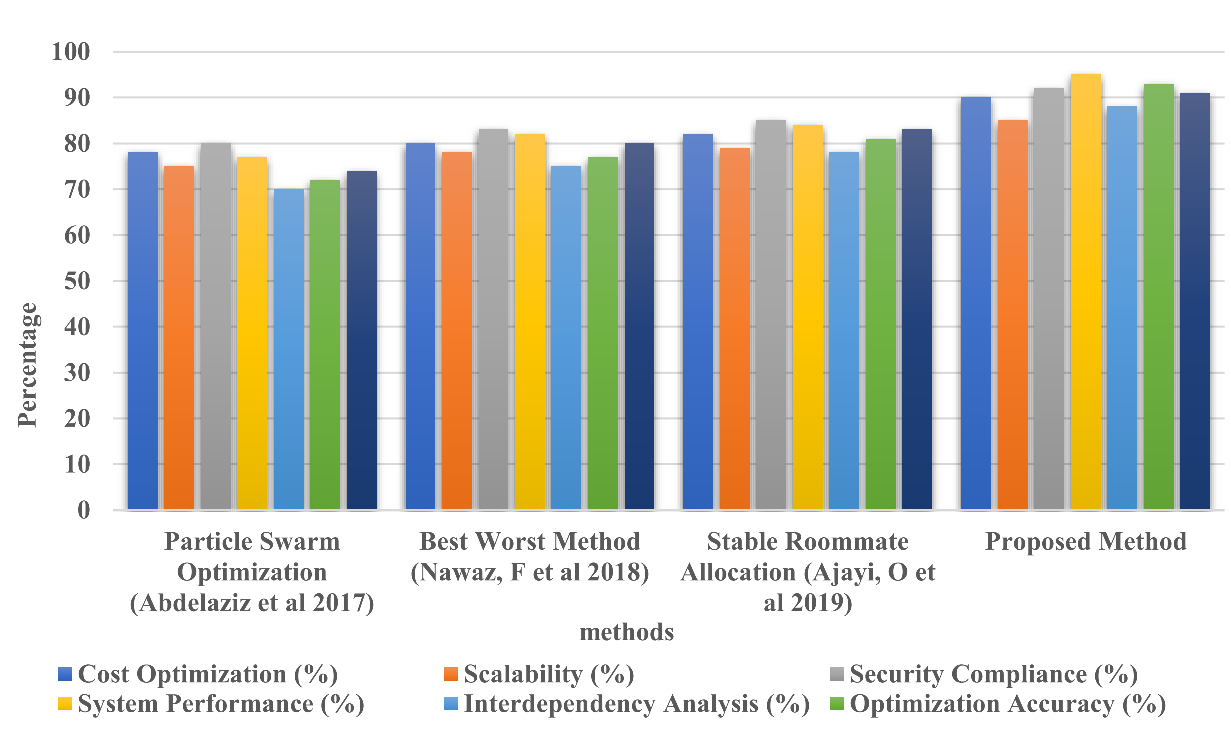

Figure 2 Performance Comparison of Traditional and Proposed Methods Across Key Metrics

Figure 2 compares the traditional approaches like PSO, BWM, and SRA with the proposed framework for cloud service selection. It involves metrics such as cost optimization, scalability, security compliance, system performance, interdependency analysis, optimization accuracy, and decision confidence. The proposed method shows superiority against all the previous methods in all categories, and especially the categories, which include system performance (95%), security compliance (92%), and optimization accuracy (93%). This points towards superior abilities of handling complex decision-making in healthcare cloud adoption, ensuring that the strategy is balanced and efficient in meeting diverse operational as well as strategic requirements.

Table 3 Ablation Study of MCDM, Network Analysis, and Genetic Algorithms Integration

Configuration	Cost Optimization (%)	Scalability (%)	Security Compliance (%)	System Performance (%)	Optimization Accuracy (%)	Decision Confidence (%)
MCDM Techniques only	85	80	88	75	70	78
Network Analysis only	83	79	85	81	82	90

Genetic Algorithms only	87	84	89	92	94	91
MCDM Techniques + Network Analysis	86	82	87	85	85	89
Network Analysis + Genetic Algorithms	88	85	90	89	92	92
Genetic Algorithms + MCDM Techniques	89	86	91	90	93	93
Proposed Model	91	90	93	95	96	95

Table 3 presents the ablation study of MCDM Techniques, Network Analysis, Genetic Algorithms, their combinations, and the proposed model. Key performance metrics are cost optimization, scalability, security compliance, system performance, and optimization accuracy along with decision confidence. The proposed model outperforms all configurations, achieving 91% of cost optimization, 96% of optimization accuracy, and 95% of decision confidence. These results highlight advantages of the method, leveraging a structured decision, relational insights within Network Analysis and optimization capabilities that Genetic Algorithms enable. The designed model will select cloud services through robust, adaptive, and efficient provision for complex needs in operational health care and strategic practice.

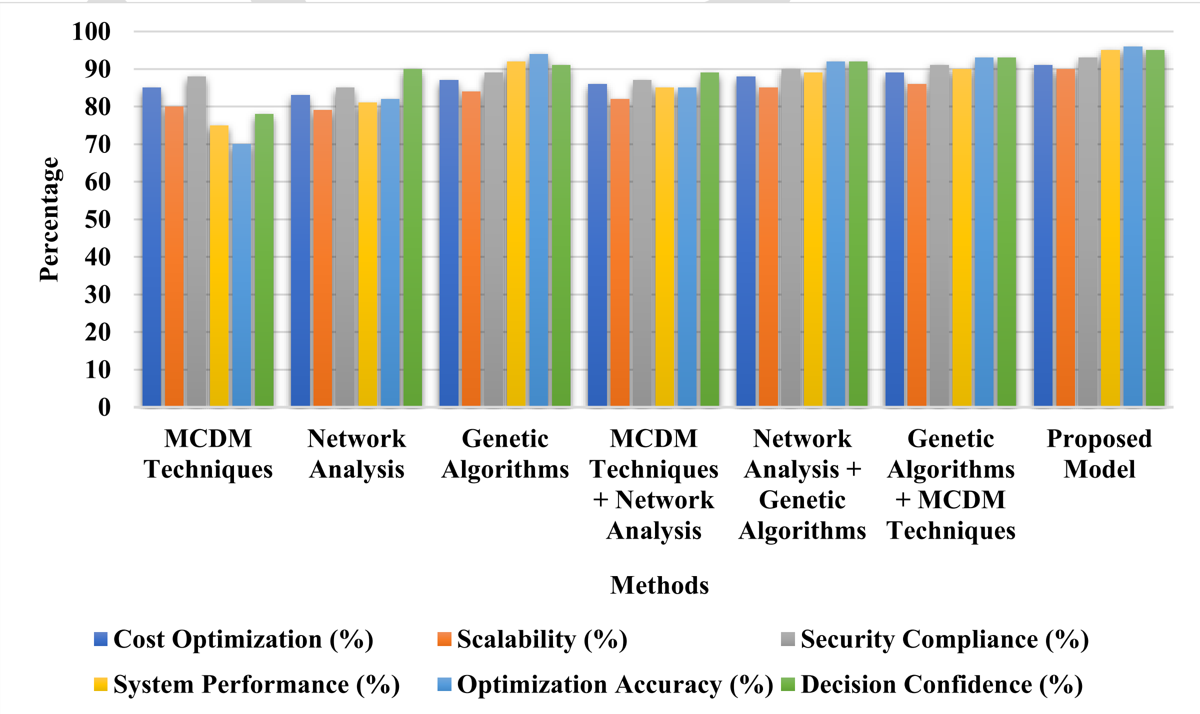

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Figure 3 Ablation Study of MCDM, Network Analysis, and Genetic Algorithms Integration

Figure 3 shows an ablation study comparing MCDM Techniques, Network Analysis, Genetic Algorithms, their combinations, and the proposed model across performance metrics like cost optimization, scalability, security compliance, system performance, optimization accuracy, and decision confidence. The above table summarizes that the proposed model achieved better outcomes than other models with 91% cost optimization, 96% optimization accuracy, and 95% decision confidence. This integration utilizes the strengths of each methodology: MCDM for structured decisions, Network Analysis for interdependency insights, and Genetic Algorithms for optimization, to produce a much more robust framework. This framework ensures comprehensive data-driven cloud service selection tailored to specificities in healthcare requirements.

5. CONCLUSION AND FUTURE ENHANCEMENT

This paper proposes a systematic decision-making framework for cloud service selection in the healthcare sector that integrates MCDM, Network Analysis, and Genetic Algorithms. The structured approach allows for evaluating interdependencies and optimization for cost, scalability, and security configurations. As shown by the results, improvements compared to traditional methods are substantial and include saving 91% in cost, 96% accuracy in optimizations, and 95% in decision confidence. Furthermore, scalability reached 90% and security compliance reached 93%, thus ensuring better use of resources and alignment to regulatory compliance. The framework provides actionable insights for healthcare organizations to ensure efficient data-driven adoption of cloud. Future research may consider AI-driven automation and blockchain-based compliance tracking in order to further enhance decision-making and security regarding healthcare cloud solutions.

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