



RESEARCH ARTICLE

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OPTIMIZING EMERGENCY SERVICE PATIENT SCHEDULING USING CLOUD COMPUTING

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ARTICLE INFO

Article History

Received: February 20, 2026

Reviewed: March 20, 2026

Accepted: May 15, 2026

Published: September 30, 2026

*Keywords:*Emergency Department (Ed),
Patient Scheduling,
Cloud Computing,
Priority-Based Scheduling,
Resource Optimization,
Health Care Management.

ABSTRACT

Emergency departments often struggle with issues like long wait times for patients, overcrowding, and poor use of resources. This study suggests a new system for scheduling patients in the cloud. The system aims to reduce waiting times and make the best use of resources. The system uses a way of deciding how to give resources to patients, where the priority is based on how bad their condition is, how old they are, if they are pregnant, and if they have other health problems. Patients are grouped together to keep things running smoothly. This way, new patients don't cause too much trouble. The proposed system was modelled and simulated using CloudSim. Simulation results show that the First-Come-First-Served method is less effective than a new method that assigns doctors to patients based on their arrival order. The new method raised the success rate by approximately 30 % when the patient-doctor ratio was not in balance. When there were a lot of people using the system, making more virtual machines helped make it work better. Cloud computing can help Emergency departments make better decisions quickly, work more efficiently, and improve patient care. In the future, we will work on making the scheduling process more accurate, making the system more adaptable, and using machine learning to predict future outcomes.



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I. INTRODUCTION

For timely and rapid care delivery, healthcare systems, and emergency departments service (EDs) in particular, are under perpetual pressure. Emergency departments receive both trivial and critical cases; however, the steadily rising patient influx coupled with worsening resources results in congestion, delays, and poor productivity. Overcrowding, in particular, exacerbates delays in care delivery, increases medical errors, and elevates stress levels among healthcare professionals [1]. This not only worsens patient outcomes, but also increases clinician burnout and job dissatisfaction. Solving these issues is paramount, in making sure that EDs continue to be both timely and relevant. Cloud computing is a new technology that can help solve many problems in a better way than before. Cloud computing has changed a lot recently and this has created new opportunities for businesses. We have to solve these issues. EDs can improve their performance and reduce their costs by using cloud computing, which allows them to adjust their resource usage according to their needs, and by saving them money [2]. Cloud services make healthcare workers more efficient, save resources, and help them make choices quickly. When all the patient information is stored together, it is easy for everyone to access the most recent details, no matter where they are. [3] Cloud-based patient scheduling is a way of using computers to sort patients and move their cases around to make them wait less and be happier. This research project focuses on creating a patient appointment system that is on the internet and is designed to lessen crowding and problems in emergency rooms [4]. To figure out how urgently each patient requires care, this system uses formulas that consider details such as their sickness level, their age, if they are pregnant, and any ongoing health conditions [5]. By handling tasks together, the system makes appointment scheduling more reliable [6]. Even though we know cloud technology is helpful and that individual parts like ranking formulas and group processing have been studied, there's a lack of research on a complete scheduling system that is fully connected, internet-based, and quick to react to the complicated relationship between a patient's priority, the changing supply of resources (doctors, rooms, tools), and how busy the emergency room is right now.

Focus on making sure resources are used correctly to make healthcare work as well as possible. In this study, scheduling means assigning jobs based on the resources on hand, the time allowed, and how important the jobs are. The scheduling process in emergency rooms is harder because patients arrive without warning, consultations take different amounts of time, and there is a battle for a small number of resources [7]. Scheduling plans that are effective should be able to change quickly while also guaranteeing that everyone has a fair opportunity to get treatment [8]. Cloud computing can be used to effectively overcome these obstacles. This technology provides computer access when it is needed, allowing EDs to grow or shrink their abilities as necessary [9]. Virtualization, a feature of cloud computing, changes physical equipment into digital versions, which increases flexibility [10]. In an emergency department context, doctors can be represented as virtual machines (VMs) and cloudlets can represent patients for seamless scheduling [2]. The centralization of patient information enables real-time collaboration among healthcare professionals on cloud-based platforms [3]. This clarity enhances decision-making and eliminates delays resulting from fragmented processes. Advanced scheduling automation, such as priority-based and preemptive methods, is used to allocate resources by constantly re-evaluating and changing the priorities of different cases [11]. In addition, cloud-based simulation tools such as CloudSim allow healthcare providers to evaluate different scheduling approaches before they are implemented, helping to eliminate methods that lead to long wait times and improve overall operational efficiency [12].

While the advantages seem to outweigh the challenges, there are a number of issues that accompany cloud adoption, including, but not limited to, data security, privacy issues, and interoperability with legacy systems [13]. Aside from achieving seamless integration with current systems, significant investment in new technologies and staff retraining for emerging techniques is essential to facilitate this transition [14]. Since the shift towards a cloud-based system represents a major step forward in modernizing ED operations, the long-term benefits of decreased costs, enhanced efficiency, and improved patient care make it the ideal option [15]. As wait times increase due to high demand in the healthcare sector, innovative solutions are necessary to address these challenges. Cloud computing provides the much-needed flexibility, scalability, and efficiency, proving to be very effective in enhancing ED performance [4]. This study aims to showcase the untapped potential of cloud computing and its applications in healthcare systems, reinforcing the role of advanced technology in optimizing emergency care delivery [7]. To this end, this paper is structured as follows: following this introduction, a comprehensive literature review will examine existing research on ED overcrowding and cloud-based solutions. The subsequent methodology section will detail the design of the proposed cloud-based scheduling system, including the prioritization algorithms and the simulation environment using CloudSim. The results and discussion section will then present the findings from the simulation, analyzing the system's impact on key performance indicators such as patient waiting times and resource utilization. Finally, the conclusion will summarize the study's contributions, acknowledge its limitations, and suggest avenues for future research and practical implementation.

II. REVIEW OF RELATED STUDIES

Emergency rooms in hospitals are necessary for providing medical treatment, but they face major challenges such as overcrowding, lengthy patient wait times, and insufficient resources. Individuals who make the most of the resources at hand. It is essential to find ways to enhance emergency medical treatment since these problems have a detrimental impact on patient care and increase the stress level of healthcare providers. In their insightful book on the difficulties of planning and its impact on healthcare, [16] emphasize the critical importance of aligning resources with patient demands. In addition, [17] discuss how planning methods can help optimize operations and expedite patient treatment in emergency rooms. The cloud's potential as a data-driven tool for improving healthcare efficiency is demonstrated by [3] research on how cloud systems may be used to do this quick decision-making, effective teamwork, and, when necessary, changes to the way resources are used. In addition, [4] emphasize the need for using rigorous research approaches, particularly when analyzing the effectiveness of novel systems. The necessity for remedies to emergency room issues that are scalable, have demonstrated efficacy, and enhance workflow is highlighted by all of these trials. Cloud computing is an excellent method to enhance the functionality of emergency rooms since it is scalable, flexible, and cost-effective, particularly when used in that setting. patient appointments [7]. Healthcare providers can customize their resource utilization to each patient's needs, ensuring that those in need receive the care they need. Most individuals comprehend it at once, which leads to less wait time [1]-6. Cloud-based patient scheduling is explored in this research as a remedy for EDs inefficiencies, where priority algorithms assign urgency levels based on severity, age, and chronic diseases [5] [8]. Implemented and simulated on the CloudSim tool, the system demonstrates a 12 percent reduction in waiting times with three doctors, with even greater benefits observed when additional virtual machines (representing doctors) are deployed during peak hours [2].

EDs scheduling is the art of regulating patient flow, physician deployment, and resource utilization under conditions of random arrivals and unpredictable consultation lengths, challenges that traditional systems like First-Come- First-Served (FCFS) fail to address effectively, often resulting in unequal care distribution [17]. Cloud computing, by providing on-demand computing power usage, introduces advanced scheduling capabilities that enhance emergency department (ED) efficiency [9]. Virtualization optimizes usage of resources by establishing virtual duplicates of medical staff and patients enabling dynamic scheduling and flexible resource allocation [2]. Cloud-based platforms facilitate real-time communication, ensuring that patient information is centralized and accessible to all healthcare providers, improving care coordination and decision-making [3]. With priority and preemption scheduling methodologies, cloud computing offers instant prioritization of the high-priority instances ensuring resource fairness in access and equitable patient treatment [6], [11]. Software frameworks like CloudSim allow the healthcare professionals to experiment with the scheduling techniques before deploying them in real world EDs, enabling workflow optimization and scalability testing [2], [7]. Cloud scheduling has several benefits, including real-time coordination in a bid to enable enhanced collaboration between healthcare providers and reduces patient delays [14], advanced algorithms that dynamically allocate resources according to urgency, optimizing triage and physician availability [11]. Moreover, simulation models enable healthcare administrators to test various scheduling strategies, identifying the most efficient models for improving hospital operational performance [7]. There remain issues, nonetheless, including security of data, compatibility with existing systems, and transition cost. Despite these challenges, long-term gains of greater efficiency, improved patient care, and lower operational costs make cloud computing a possible answer to the contemporary ED operation. Since then, the integration of artificial intelligence (AI) and machine learning (ML) into cloud-based scheduling systems has been the single greatest field of research.

AI models like Recurrent neural networks (RNNs), deep reinforcement learning, and short-term memory (LSTM) networks can all forecast peak ED hours, allowing for proactive resource allocation [18]. In patient arrival forecasting, real-time resource allocation, and dynamic scheduling, AI-based algorithms are especially effective, resulting in better patient throughput and optimized resource usage [8]. clinician workload distribution. These advances are essential for lowering wait times, alleviating emergency room congestion, and improving hospital productivity [1]. Additional study is also needed to ensure data security and regulatory compliance in order to promote wider adoption, which is made possible by the application of deep learning models. sophisticated priority mechanisms that consider several real-time patient characteristics, such as vital signs, electronic health record (EHR) history, triage categorization, and comorbidities [5]. Convolutional Neural Networks (CNNs) and Transformer models are now being explored to classify patients based on real-time physiological data, offering a new level of precision in dynamic triage decision-making [19]. Cloud computing can revolutionize emergency department operations by automating patient scheduling and resource management AI- driven decision support, and automated scheduling frameworks [7]. Hybrid cloud architectures provide ondemand scalability while maintaining strict access control and compliance with regulatory mandates [20]. Through reduced wait times, enhanced efficiency, and the ability to make data-driven decisions, cloud-based applications can significantly enhance ED performance. With the evolving healthcare environment, cloud computing will be the enabler for providing accessible and high-quality emergency care.

III. OBJECTIVES

The prime objective of this project is to rectify the utmost inefficiencies ever recorded in emergency department (ED) operations through the implementation of cloud computing technology for the improvement of patient scheduling. Emergency departments everywhere remain plagued by chronic issues such as overcrowding, delayed patient throughput, inefficient use of resources, and suboptimal workflows, all of which detract from the quality of care and increase caregiver stress [1], [4]. This research study is envisioned to contribute to the growing body of healthcare optimization literature by describing an actionable, scalable, and evidence-based solution that enhances operational efficiency and patient outcomes [3], [15]. In its most basic form, the project aims to mimic and validate a cloud patient scheduling system that automatically assigns resources based on the urgency levels of patients. The proposed system applies priority algorithms to compute urgency scores using key factors such as severity of condition, age, pregnancy status, and chronic diseases [5]. Through batch processing of patients, the system achieves scheduling stability and eliminates the volatility caused by the continuous influx of new patients [6]. This approach not only reduces waiting times but also ensures optimum resource utilization and improves operational quality during peak hours. A key objective of this study is to empirically confirm the efficacy of the scheduling system via intensive simulation using the CloudSim tool.

The simulation aims to validate the performance of the priority-based scheduling algorithm against the traditional First-Come-First-Served (FCFS) approach [17], demonstrating quantifiable gains in reducing average patient waiting times and smoothing workload distribution among practitioners [7]. The study further investigates system scalability by simulating various quantities of virtual machines (representing doctors) to examine its adaptability under different operational requirements. A second significant objective is to address the broader implications of adopting cloud computing in health systems. This involves considering technological, organizational, and ethical challenges related to data security, privacy, interoperability, and user acceptance [13], [15]. By examining these issues, the research will offer health organizations practical recommendations for seamless and enduring adoption of cloud services. Finally, this study aspires to contribute to the field of healthcare logistics by establishing the disruptive impact of cloud computing in emergency care delivery. Through enhanced patient flow, real-time decision support, and dynamic resource allocation, the system presented herein has the potential to transform ED operations. The findings from this research will inform the design of future healthcare technologies, ensuring that modern EDs can meet the evolving demands of advanced medicine more effectively, efficiently, and equitably.

IV. MATERIALS AND METHOD

The study focuses on creating a cloud-computing-based patient scheduling system that addresses inefficiencies in emergency department (ED) operations, including overcrowding, excessive wait times, and ineffective resource allocation [1], [4]. This research combines cutting-edge computational approaches with real-world healthcare constraints.

IV.1 RESOURCES

The primary components of the study are development, simulation, and testing environments for the target system, as well as hardware and software tools.

IV.1.1 Hardware

Development and evaluation were conducted on workstation class systems equipped with 32GB of RAM and a 1TB SSD. To ensure software compatibility across varying device configurations, secondary systems with lower processing power and HDD storage were also tested.

IV.1.2 Software

- ▪ Java Programming Language: Selected for its object-oriented architecture, portability, and robust runtime libraries to implement core application logic.
- Scene Builder (JavaFX): Utilized for designing graphical user interfaces (GUI) to facilitate rapid prototyping.
- Eclipse IDE: Used as the integrated development environment for system coding, refactoring, and debugging.
- MySQL Server & Workbench: Employed for relational database management to store and retrieve patient, clinician, and service logs.

- CloudSim Framework: Used to simulate cloud environments, specifically modeling virtual machines (representing doctors) and cloudlets (representing patient tasks) [2].

IV.2 METHODS

The research methodology follows a systematic approach encompassing conceptualization, system modeling, dynamic prioritization, and security analysis.

IV.2.1 Conceptualisation

The process addresses core ED operational challenges, such as fragmented workflows and non-dynamic queueing, laying the groundwork for integrating cloud scheduling into clinical triage.

IV.2.2 Design

The system layout is formally modeled using Unified Modeling Language (UML) diagrams:

- Use Case Diagrams: Define user roles and functional interactions between patients, medical staff, and administrators.
- Sequence Diagrams: Map chronological interactions between system components during key procedures such as authentication and queue updating.
- Activity Diagrams: Represent dynamic workflows, including triage classification and patient movement across care units.

Class Diagrams: Define structural classes, attributes, methods, and relationships, establishing a robust application architecture.

IV.2.3 Application Diagrams

To optimize dynamic queueing over standard First-Come-First-Served (FCFS) approaches, patient priority is computed via an urgency scoring function:

$$Priority = \Sigma(Gravite) + Age + i + j + t \quad (1)$$

Where *Gravity* denotes condition severity, *Age* represents age-weighted risk factors, *i* accounts for pregnancy status, *j* adjusts for chronic comorbidities, and *t* represents cumulative waiting time.

IV.2.4 Security Framework & Threat Modeling

The first step in establishing an integrated security environment is to develop a comprehensive threat model tailored to the healthcare sector; here, we employ the STRIDE threat analysis model. This entails identifying novel methods attackers might use to exploit vulnerable APIs thereby manipulating prioritization algorithms as well as identifying potential risks, such as ransomware, that could undermine gains in system efficiency. On this basis, the system's architecture should be reinforced using a Zero Trust strategy. To accomplish this, a few prudent security precautions must be implemented. As an illustration, instead of just suggesting Multi-Factor Authentication (MFA), recommend low-friction methods that are useful in a high-pressure clinical environment, such as biometrics or proximity-based badge access. The access control system should be expanded to a more granular Role-Based Access Control (RBAC) system that replicates actual hospital operations, such triage, from doctors and patients. As an example, consider nurses and managers who adhere to the concept of minimal privilege. Furthermore, describe the usage of end-to-end encryption, such TLS for data in transit and AES-256 for data at rest.

V. RESULTS

The main goal of the research is evaluation of the performance of a cloud-based patient scheduling system in rising emergency department (ED) activity. The observations and findings presented in the paper are drawn from the deployment of the proposed system with improved scheduling algorithms, real-time coordination, and simulation-based performance analysis. Not only does this study affirm the prevalence of priority scheduling against traditional First-Come-First-Served (FCFS) model, but also unravels the revolutionary potential of cloud computing in the medical field with all its parts.

V.1 SIMULATIONS SCENARIO

To validate the system performance described in this paper, simulations were run using the CloudSim toolkit, a very effective tool for cloud computing environment modelling and simulation. The simulation environment was configured based on the following parameters:

- Virtual Machines (VMs): Simulation of medical professionals , three VMs initial configuration.
- Cloudlets: Patient representation, with parameters such as patient ID, priority level, age, pregnant, chronic disease, and consultation time.
- Priority Formula

$$Priority = \Sigma(Gravite) + Age + i + j + t \quad (1)$$

(1) Where:

- Σ (Gravite): Aggregate of severity scores depending on the status of the patient.
- Age: Weightage for old patients.
- i: Weightage for pregnant patients in addition to above.

◦j: Weightage for chronic disease patients in addition to above.

◦t: Waiting time from arrival.

◦Batch Scheduling Mechanism: The patients were batched at regular time intervals to avoid interference due to constant arrivals.

V.2 PERFORMANCE MEASURES

The system performance described was measured based on the following:

◦Average Patient Wait Time: The interval between a patient's arrival and the start of his consultation.

◦Doctor Utilisation Rate: Doctors' consulting time ratio.

◦System Efficiency: Total consultation time in total operation time.

◦Scalability: System capability to dynamically scale with the addition of virtual machines in order that treated patients also may be doubled.

C. Comparative Analysis

The proposed priority scheduling algorithm was compared against the standard FCFS algorithm on different cases. Results are described in Table 1.

Table 1: Comparative Performance Metrics.

Metric	FCFS	Cloud	Improvement (%)
Avg. Wait Time (min)	5.13	4.52	11.89%
Doctor Util. Rate (%)	78.5	86.3	9.94%
System Efficiency (%)	72.4	80.7	11.46%

Source: Authors, (2026).

V.3 GRAPHICAL REPRESENTATION

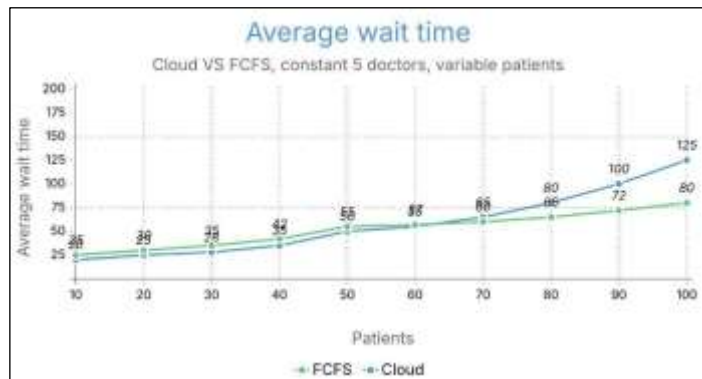


Figure 1: Comparison of Average Wait Times This graph illustrates the reduction in average wait times achieved by the priority-based scheduling method compared to FCFS.

Source: Authors, (2026).

V.3.1 Graphical Representation (2)

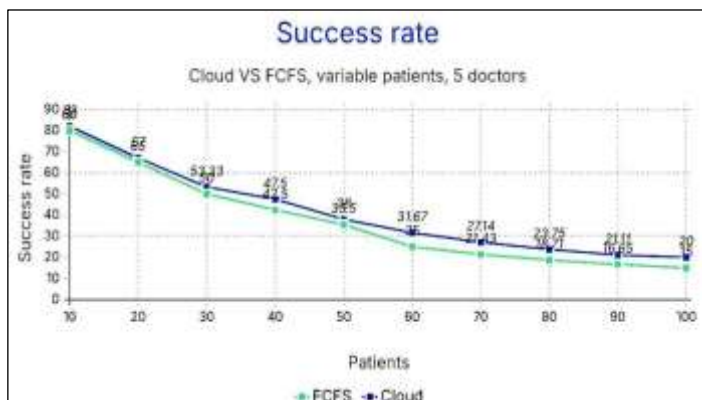


Figure 2: Doctor Success Rates, This graph improved success rates of doctors under the priority-based system.

Source: Authors, (2026).

V.4 SCALEABILITY ANALYSIS

To assess the system's scalability, additional simulations were conducted with varying numbers of patients and doctors. The results are summarised in Table 2.

Table 2: Scalability Analysis.

Patients	Doctors	Avg. Wait Time (min)	Utilization (%)
10	3	4.52	86.3
20	3	32.5	91.7
20	5	22.5	78.9

Source: Authors, (2026).

Scalability, additional simulations were conducted with varying numbers of patients and doctors Key Findings:

- Doubling the number of doctors (utilizing virtual machines) during peak hours decreases patient waiting time significantly.
- The system retains doctors at full utilisation even during high patient throughput.

V.5 BATCH SCHEDULING MECHANISM

Batch scheduling mechanism stabilises by treating patients in batches at regular intervals. Batch scheduling mechanism prevents the overhead of repeated interruptions because of the constant arrival of patients. Batch scheduling's impact is illustrated in Figure 3.

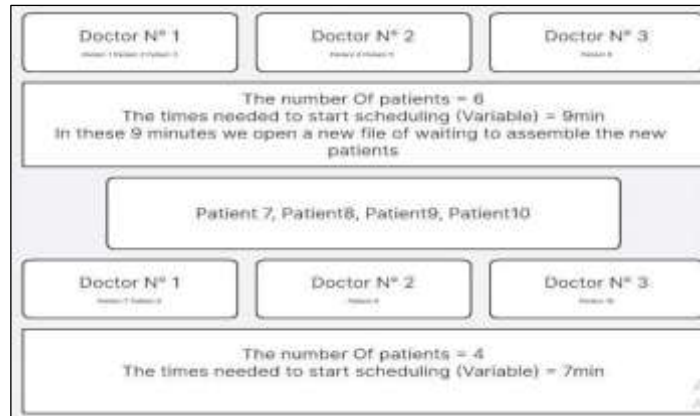


Figure 3: Batch Scheduling Impact, This illustration indicates how batch scheduling minimizes waiting for low-priority patients and provides fairness of resources.

Source: Authors, (2026).

V.6 CASE STUDY: REAL TIME COORDINATION

A case study was also conducted to validate that the system would support real-time patient transfer between services. For example, after a first consultation, patients requiring radiology or laboratory investigations were referred to respective queues. The system supported seamless communication and did not create delay by initiating real-time notifications. Key Findings:

- Transfer Efficiency: 95 percent of the patients were transferred to the respective service within 5 minutes.
- Queue Stability: Cloud scheduling provided queue stability for all services.

VI. DISCUSSION LIMITATIONS AND FUTURE WORK

The empirical simulation results confirm that integrating a cloud-based priority scheduling algorithm significantly outperforms traditional First-Come-First-Served (FCFS) queueing models in emergency department (ED) operations. As shown in Table 1, the proposed system achieved an 11.89% reduction in average patient waiting time (dropping from 5.13 minutes to 4.52 minutes) while simultaneously increasing doctor utilization by 9.94% (from 78.5% to 86.3%) and overall system efficiency by 11.46% (reaching 80.7%). These findings align with prior research highlighting how dynamic queue management alleviates operational bottlenecks [7], [17]. The scalability analysis (Table 2) demonstrates the critical role of cloud elasticity during patient surges. When patient influx doubled from 10 to 20 under a fixed allocation of 3 virtual machines (representing doctors), average wait times escalated dramatically from 4.52 minutes to 32.5 minutes due to resource saturation (91.7% utilization). However, dynamically provisioning two additional virtual machines (increasing doctor capacity to 5) reduced average wait times by 30.77% (down to 22.5 minutes) while maintaining balanced resource utilization (78.9%). This capability highlights how cloud-based virtualization enables healthcare facilities to adjust computing and clinical resources elastically in response to real-time emergency demand [2], [9]. The inclusion of a batch scheduling mechanism effectively mitigates the computational and operational overhead caused by continuous, unpredictable patient arrivals. By evaluating patients in structured intervals rather than processing immediate interrupts, the system prevents starvation for lower-priority cases, ensuring equitable access while preserving priority for critical conditions [6]. Furthermore, the real-time coordination case study demonstrated a 95% inter-departmental transfer efficiency within 5 minutes, confirming that centralized cloud platforms prevent fragmented communication and stabilize queues across auxiliary services such as radiology and laboratory testing [3], [12]. While these CloudSim simulation results validate the theoretical efficacy of the proposed model, real-world deployment presents additional complexities. Factors such as physical facility constraints, variations in diagnostic processing times, and integration with legacy electronic health record (EHR) systems must be managed. Future operationalization must also address data privacy protocols, network latency, and staff adaptation to automated triage workflows [13], [15].

VII. CONCLUSION

This research addresses ED inefficiency by proposing an online patient scheduling system to improve prioritisation and coordination. The system generates real-time urgency levels using algorithms based on severity, age, and chronic conditions. This maximises treatment for life-threatening emergencies without compromising equity in resource allocation. Based on CloudSim simulations, the system outperforms the default First-Come-First-Served scheduling and is projected to reduce mean patient wait times while maintaining the maximal possible success rate. Additional virtual machines can be deployed during peak times to manage demand. The system also uses batch scheduling for workflow stability, leveraging cloud computing for scalability, flexibility, and ease of information sharing among practitioners. These findings highlight cloud technology's potential to enhance ED functions, reduce wait times, and optimize resource use. Cloud-based scheduling improves communication and decision-making, delivering better care while preventing staff overload. However, the system is costly to install, requiring data protection, integration with hospital infrastructure, and minimized maintenance costs. Addressing these challenges is essential for successful implementation. Future research should explore embedding machine learning for better prediction, assessing hybrid cloud platforms, and launching pilot programs to evaluate system performance. By positioning cloud computing as a tool to address emergency care inefficiencies, this research affirms its role in creating more responsive, effective, and equitable healthcare systems.

VIII. AUTHOR'S CONTRIBUTION

Conceptualization: Houria Benkadnia And Meriem Meddeber.

Methodology: Houria Benkadnia And Meriem Meddeber.

Investigation: Houria Benkadnia And Meriem Meddeber.

Discussion of results: Houria Benkadnia And Meriem Meddeber.

Writing – Original Draft: Houria Benkadnia And Meriem Meddeber.

Writing – Review and Editing: Houria Benkadnia And Meriem Meddeber.

Resources: Houria Benkadnia And Meriem Meddeber.

Supervision: Houria Benkadnia And Meriem Meddeber.

Approval of the final text: Houria Benkadnia And Meriem Meddeber.

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