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Development of a digital intensive care unit visitation management system

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ABSTRACT

This study develops and assesses the prototype-level feasibility of a web-based digital system for intensive care unit (ICU) patient visitation management. The system was developed using the rapid application development (RAD) approach, comprising requirements planning, user design, construction, and implementation. The prototype integrates visitor registration, identity verification, visit scheduling, room-capacity management, quick response-based (QR-based) visitor authorization, visit-duration monitoring, notifications, and reporting within a unified workflow. Prototype-level feasibility was examined from technical, economic, operational, legal, and ethical perspectives and was complemented by a functional comparison with conventional ICU visiting procedures and strengths, weaknesses, opportunities, and threats (SWOT) analysis. The findings indicate that the proposed workflow is technically implementable using established web technologies and provides a more structured mechanism for managing visitor registration, authorization, scheduling, capacity, and visit documentation. However, the present findings represent prototype-level feasibility rather than evidence of quantitative usability, clinical effectiveness, or real-world operational improvement. Further research should evaluate usability, system performance, security, interoperability, and workflow impact through pilot deployment in operational hospital environments.

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1. INTRODUCTION

Hospitalization in an intensive care unit (ICU) can impose substantial psychological and emotional burdens on patients and their families. Family visitation is an important component of patient- and family-centered critical care and has been associated with improved patient and family experiences. Previous studies have reported potential benefits of less restrictive ICU visitation policies, including improved family satisfaction and favorable patient-related outcomes. Accordingly, appropriate family access during hospitalization represents an important component of patient- and family-centered care [1], [2].

Conversely, restrictive visitation policies may negatively affect patients, family members, and healthcare professionals. Reported consequences include patient isolation, family anxiety, and psychological

or moral distress among healthcare personnel [3]–[5]. These concerns became particularly evident during the COVID-19 pandemic, when hospitals substantially restricted or prohibited family visitation as part of infection-control measures [6].

Raphael *et al.* [7] highlighted unintended consequences of restrictive visitation policies during the COVID-19 pandemic, including concerns that visitation restrictions could influence families' decisions regarding hospital care. Such restrictions may therefore have implications beyond infection control and should be balanced against patient- and family-centered care requirements [3]. Previous evaluations of hospital visitation policies during the COVID-19 pandemic have consequently emphasized the need for a balanced and patient-centered approach that considers patients, visitors, and healthcare personnel [8].

These findings indicate that ICU visitation requires a balance between family access and the operational, safety, and capacity constraints of critical-care environments. Preliminary empirical evidence from the study setting further indicates that visitation is relevant to the inpatient experience. Among hospitalized patients who reported having visitors (N=61), 60 respondents (98%) indicated that visitor presence improved their overall well-being and satisfaction, while 53 respondents (87%) reported that visitors contributed to supporting their care after discharge. Among patients who reported having no visitors (N=177), 70 respondents (40%) perceived that the absence of visitors reduced their overall well-being and satisfaction, while 104 respondents (59%) indicated that their care would have been better if visitors had been permitted. In addition, 83 respondents (47%) reported that the absence of visitation made it more difficult for family members or caregivers to obtain information about the patient's hospital care. These findings provide contextual evidence that ICU visitation is not solely an administrative matter but is also relevant to patients' and families' experiences of hospital care. From an information-systems perspective, achieving this balance requires more than defining visitation rules. Hospitals also need mechanisms for visitor registration, identity verification, scheduling, access authorization, capacity control, visit-duration monitoring, and documentation. When these processes are performed manually or independently, consistent implementation, and real-time monitoring of visitation policies can become difficult.

The operational context was further examined through a questionnaire involving 200 respondents. The results indicated that 158 respondents (79.0%) reported that conventional visitation procedures were still being used, while 150 respondents (75.0%) indicated that visitor information was recorded manually. Furthermore, 132 respondents (66.0%) reported difficulties in accessing important visitor-related information, and 162 respondents (81.0%) indicated that online visitor registration had not yet been used. Notably, 178 respondents (89.0%) indicated a need for a more systematic online visitor-registration mechanism. These findings provided empirical support for prioritizing digital registration, scheduling, authorization, capacity management, and visitor-information management within the proposed system.

Existing hospital information systems (HIS) primarily support clinical and administrative processes such as patient registration, medical records, laboratory services, billing, and other hospital operations. However, the studies reviewed in this work provide limited evidence of an integrated ICU-specific visitor-management workflow that combines registration, verification, scheduling, room-capacity control, digital visitor authorization, visit-duration monitoring, and reporting. This creates an information-system research gap: ICU visitation policies require operational mechanisms for controlling who may visit, when visits may occur, how room capacity is maintained, how visitor access is authorized, and how visit activities are recorded, yet these functions are not systematically integrated within the visitor-management approaches identified in the reviewed literature.

To address this gap, this study aims to develop a web-based digital ICU patient visiting system and assess its feasibility as a structured information-system approach for supporting hospital visitation management. The proposed system translates ICU visitation requirements into an integrated digital visitor-management workflow rather than introducing a new clinical visitation policy. A functional web-based prototype was developed using the rapid application development (RAD) approach to demonstrate the proposed workflow. The prototype integrates visitor-management functions that are conventionally handled manually or separately into a unified web-based information-system workflow.

The workflow covers visitor registration, identity verification, visit scheduling, visitor and duration restrictions, quick response-based (QR-based) digital visitor authorization, controlled access to non-medical patient information, room-capacity monitoring, and visit reporting. Visitor and visit-related information is recorded in a database to support verification, authorization, monitoring, and reporting processes. The technical contribution therefore lies in the integration of these functions into a single ICU-oriented visitor-management workflow that links registration, scheduling, capacity control, digital authorization, and visit monitoring.

The prototype is intended to provide a structured digital alternative to conventional ICU visitor-management procedures and to establish a technical basis for subsequent evaluation and broader hospital implementation. At the present stage, the system is evaluated as a prototype rather than as a fully deployed HIS. Its feasibility is examined to identify the technical and operational requirements that should be addressed before pilot implementation in a real hospital environment. Accordingly, this study does not claim large-scale

usability, clinical effectiveness, or real-world operational performance; these aspects require subsequent validation involving hospital staff and visitors in operational ICU environments. The contributions of this study are threefold: i) the design of an integrated digital workflow for ICU visitor management covering registration, verification, scheduling, capacity control, digital visitor authorization, visit-duration monitoring, and reporting; ii) the implementation of this workflow as a functional web-based prototype using the RAD approach; and iii) a prototype-level feasibility assessment covering technical, economic, operational, legal, and ethical considerations, complemented by comparison with conventional ICU visiting procedures and strengths, weaknesses, opportunities, and threats (SWOT) analysis. By supporting the digital management of hospital visitation services, the proposed system is also aligned with the broader objectives of Sustainable Development Goal 3 (SDG 3): good health and well-being.

2. RELATED WORK

Patient- and family-centered care (PFCC) is an important consideration in ICU services because visitation and communication involve not only patients but also their families and healthcare professionals. Recent qualitative research has identified organizational, structural, cultural, and communication-related barriers to implementing PFCC in ICU environments, while also highlighting the importance of flexible visitation arrangements and dedicated family-support mechanisms [9]. In addition, research on families of critically ill patients has reported unmet information needs concerning patient recovery, the timing of information delivery, and participation in decision-making, indicating the importance of structured communication between families and ICU staff [10].

Beyond the clinical context, the implementation of HIS depends on organizational readiness, adequate resources, data-management capacity, and institutional support [11]. A mixed-methods investigation of public hospitals identified financial capacity, data management, and implementation roadmaps as important determinants of HIS readiness [12]. Previous research has also shown that healthcare information-system implementation is influenced by different stakeholder perspectives, professional practices, and organizational contexts [10]. Furthermore, organizational transformation associated with HIS implementation requires coordinated attention to organizational structures, workforce capabilities, resources, and IT infrastructure [13].

Healthcare information systems have also been investigated in relation to healthcare expenditure evaluation and health monitoring [14]. In addition, workflow modeling based on unified modeling language (UML) and Coloured Timed Petri Nets has been used to analyze healthcare processes involving interactions between clinical personnel, medical devices, and information systems [15], [16].

Digital identity and access management represent another relevant consideration when information systems handle personal and patient-related information. Comparative research on national digital identity architectures has highlighted the importance of identity assurance, privacy protection, legal compliance, and interoperability when designing digital identity mechanisms [17]. In healthcare administration, mobile workflow and document-management systems have also been developed to facilitate the secure exchange, review, and processing of healthcare-related information across different working environments [18]. These studies provide complementary perspectives on workflow integration, identity-related controls, and the organization of digital administrative processes.

However, the reviewed literature primarily addresses patient- and family-centered care, general hospital information management, healthcare workflow modeling, digital identity, and hospital-related administrative applications. Limited evidence is available regarding an integrated ICU-specific visitor-management workflow that combines visitor registration, identity verification, scheduling, room-capacity control, digital visitor authorization, visit-duration monitoring, and reporting within a unified information-system workflow. This gap is important because ICU visitation policies require not only policy definition but also operational mechanisms for controlling visitor access, scheduling visits, maintaining room capacity, authorizing entry, and documenting visitation activities. Therefore, this study addresses the gap by developing a dedicated digital ICU visitor-management prototype and examining its prototype-level implementation feasibility.

3. MATERIALS AND METHODS

This study employed a prototype development approach to design and implement a web-based digital ICU patient visiting system. The system was designed to support structured visitor registration, identity verification, visit scheduling, access authorization, visit-duration control, room-capacity management, and visit documentation. Under the proposed workflow, visitor access is linked to prior registration, schedule availability, and authorization within the prototype system.

The development process required an iterative approach that could accommodate changes in functional requirements while progressively producing a functional prototype. Therefore, RAD was selected because it emphasizes rapid prototyping, iterative refinement, and active user involvement during system development [14], [15]. The use of scenarios and iterative design analysis within RAD can further support the translation of user requirements into evolving system designs [16]. Its application in healthcare information-system environments is also supported by process-oriented development approaches that integrate rapidly developed applications into healthcare information systems [19].

Furthermore, patient- and family-centered care in ICUs requires attention to organizational barriers, communication challenges, privacy concerns, and flexible family visitation arrangements [12].

RAD is an iterative software-development approach that emphasizes rapid prototyping, progressive refinement, and interaction between system developers and prospective users or stakeholders [14]–[16]. In this study, the RAD process was organized into four stages: requirements planning, user design, construction, and implementation.

These stages provided the methodological framework for translating ICU visitor-management requirements into a functional web-based prototype. The development process was iterative: system requirements identified during the initial stage were translated into interface and data-flow designs, implemented as prototype functions, and progressively refined during subsequent development cycles. The overall development workflow based on the four RAD stages is illustrated in Figure 1.

During requirements planning, the functional requirements of the ICU visitor-management system were identified and organized. These requirements included visitor registration, identity verification, visit scheduling, visitor and duration restrictions, digital visitor authorization, room-capacity management, visit monitoring, notifications, and reporting. The required data entities and relationships between system functions and data were also identified during this stage.

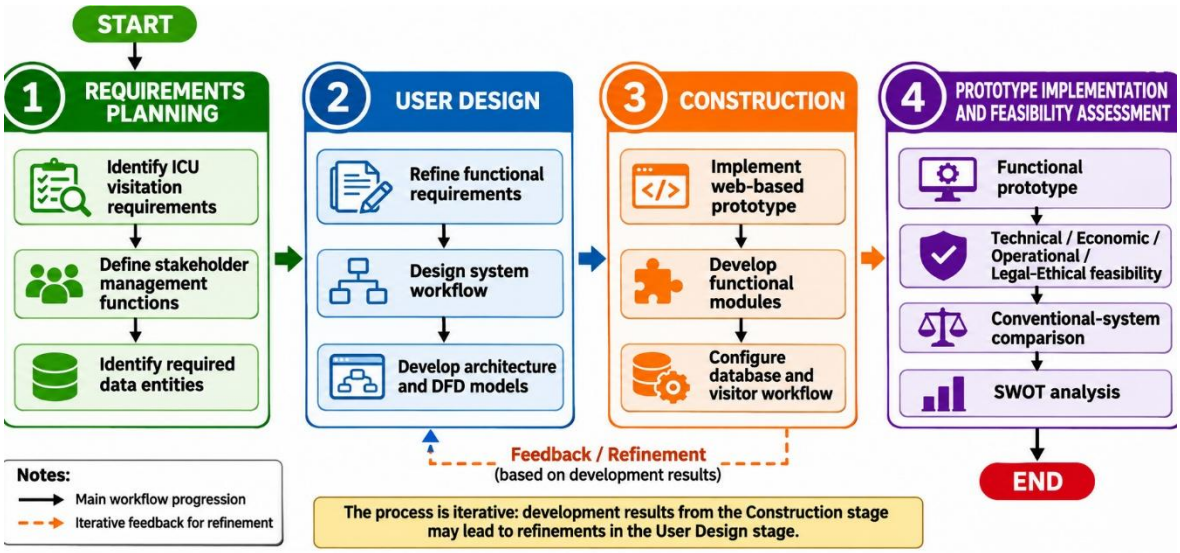


Figure 1. Research workflow based on the RAD

During the user-design stage, joint application development (JAD) was used to refine and prioritize the identified system requirements and translate them into conceptual system designs. The identified entities and functional requirements were translated into data-flow and system-design representations to describe interactions among visitors, hospital staff, ICU visitation processes, and the underlying data. The resulting system architecture defines the interaction between users, the web-based application, and the database layer, as Figure 2 illustrates. The design served as the basis for implementing the functional prototype during the construction stage.

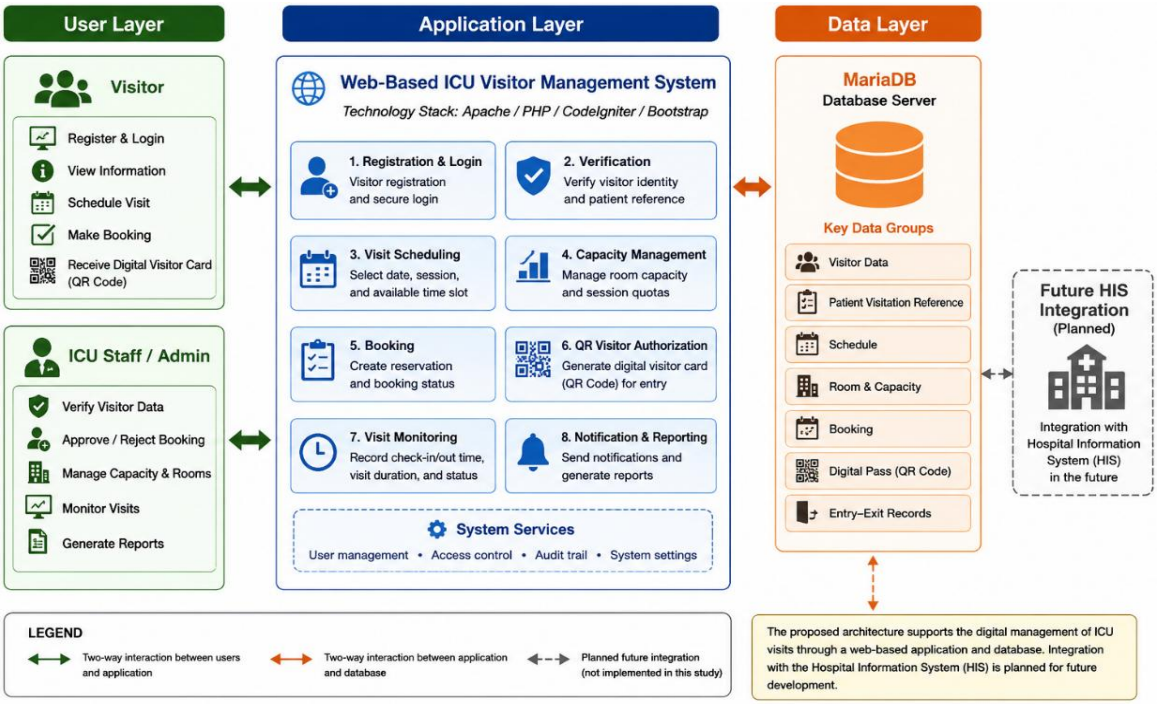


Figure 2. Architecture of the proposed web-based ICU visitor-management prototype

During the construction stage, the approved system designs were translated into functional web-based modules. Development proceeded iteratively so that individual functions could be implemented and refined according to the requirements identified during the preceding RAD stages. The conceptual data model and system workflow were implemented as a functional prototype comprising visitor registration, login, dashboard, visit scheduling, room-capacity management, booking, QR-based digital visitor authorization, and visit-notification modules. The iterative construction process allowed the prototype design and system functions to be progressively refined before implementation-level assessment. The implementation stage focused on preparing the completed prototype for feasibility assessment and identifying the technical and operational requirements that would need to be addressed before deployment in an operational hospital environment.

3.1. System requirements and prototype design

The prototype was designed as an integrated ICU visitor-management system supporting visitor registration and identity verification, visit scheduling, visitor and duration restrictions, QR-based digital visitor authorization, and room-capacity monitoring.

These functional requirements were organized into a structured workflow connecting visitor registration, visit authorization, scheduling, capacity management, entry-exit monitoring, and reporting. The design represents a prototype-level visitor-management workflow rather than a fully integrated operational HIS.

3.1.1. Functional requirements

The functional requirements were formulated based on the identified operational needs of ICU visitor management and the intended workflow of the proposed prototype. These requirements define the essential system functions for managing visitor information, controlling visitation schedules, authorizing access, and protecting patient-related information. The principal functional requirements are described as follows.

a. The visit-scheduling function was designed to manage two daily visitation sessions: session 1 from 11:00 AM to 1:00 PM and session 2 from 5:00 PM to 7:00 PM. Each authorized visitor is allocated a maximum visit duration of 30 minutes. The schedule can be adjusted when required by emergency conditions or changes in hospital visitation policy.
b. The visitor-registration function supports online or on-site registration. The required visitor information includes full name, identification number–*Kartu Tanda Penduduk/Surat Izin Mengemudi* (KTP/SIM), contact number, email address, relationship to the patient, patient name, and preferred visitation time. The submitted information is subsequently subject to verification before visit authorization.

c. Following authorization, the system generates a QR-based digital visitor card that is valid for a specific visit. The card contains the visitor's name, permitted visit duration, destination room or building, and the patient's name without displaying medical information.
d. Access to patient-related visitation information is restricted to authorized users. The information required for visitation management is limited to patient identification, room designation, and visitation status; medical information is outside the scope of the visitor-management prototype. The displayed information includes the patient's name, medical record number (restricted to internal systems), treatment room designation (ICU A/B/C), and visitation status, indicating either "can be visited" or "visiting temporarily closed."

3.1.2. Room and capacity management

The room-capacity function records the building, ICU room designation, patient capacity, and maximum number of visitors permitted for each visitation session. The system checks available capacity during scheduling and prevents additional reservations when the configured visitor quota has been reached.

3.1.3. Visit-duration monitoring

Each authorized visit is limited to a maximum duration of 30 minutes. The prototype is designed to issue an automatic notification 5 minutes before the end of the allocated period and to record visitor entry and exit times through QR-code scanning.

3.1.4. Supporting system functions

Supporting functions include an ICU staff dashboard for reviewing visitor lists, managing visit approval, and monitoring room capacity; automated visit reminders and status notifications; and reporting functions summarizing visit frequency, duration, and recorded capacity or duration violations.

3.1.5. Visitor-management workflow

The proposed workflow begins with online or on-site visitor registration. Following verification and approval, an authorized visitor receives a QR-based digital visitor card associated with the selected visit schedule. At the scheduled visitation time, the QR code is scanned at the ICU entrance to validate authorization and record entry. A subsequent scan records the visitor's exit, enabling the system to document the visit duration. Before authorization, the system checks the configured room and session capacity. Visit records are stored to support subsequent monitoring and reporting.

3.2. Conceptual system design and architecture

The conceptual system design was represented using data flow diagrams (DFDs). The context diagram defines the external entities interacting with the ICU visitor-management system and the principal information exchanges between these entities and the system, whereas the level 0 DFD decomposes the overall workflow into its main information-processing functions. The context diagram and level 0 DFD are presented in Figures 3 and 4, respectively.

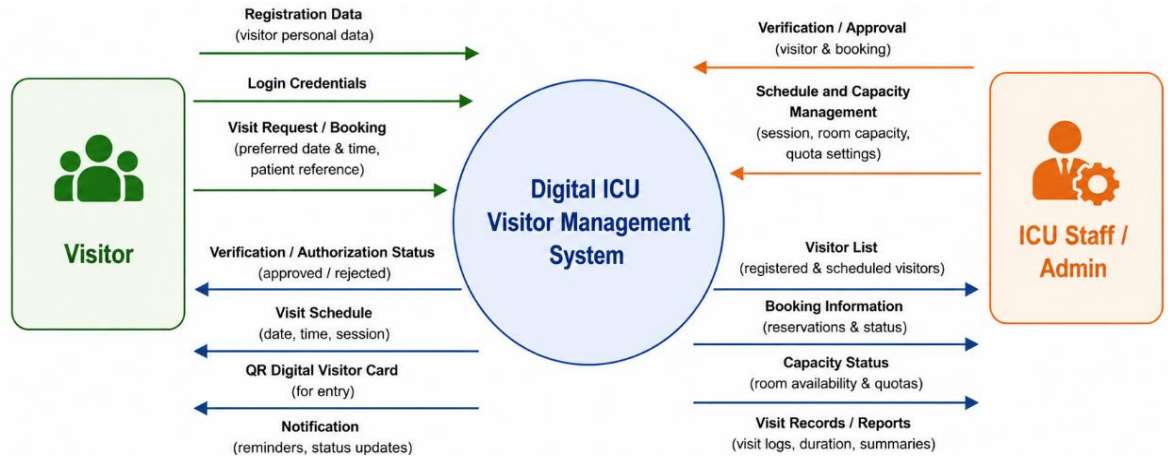


Figure 3. Context diagram of the digital ICU visitor-management system

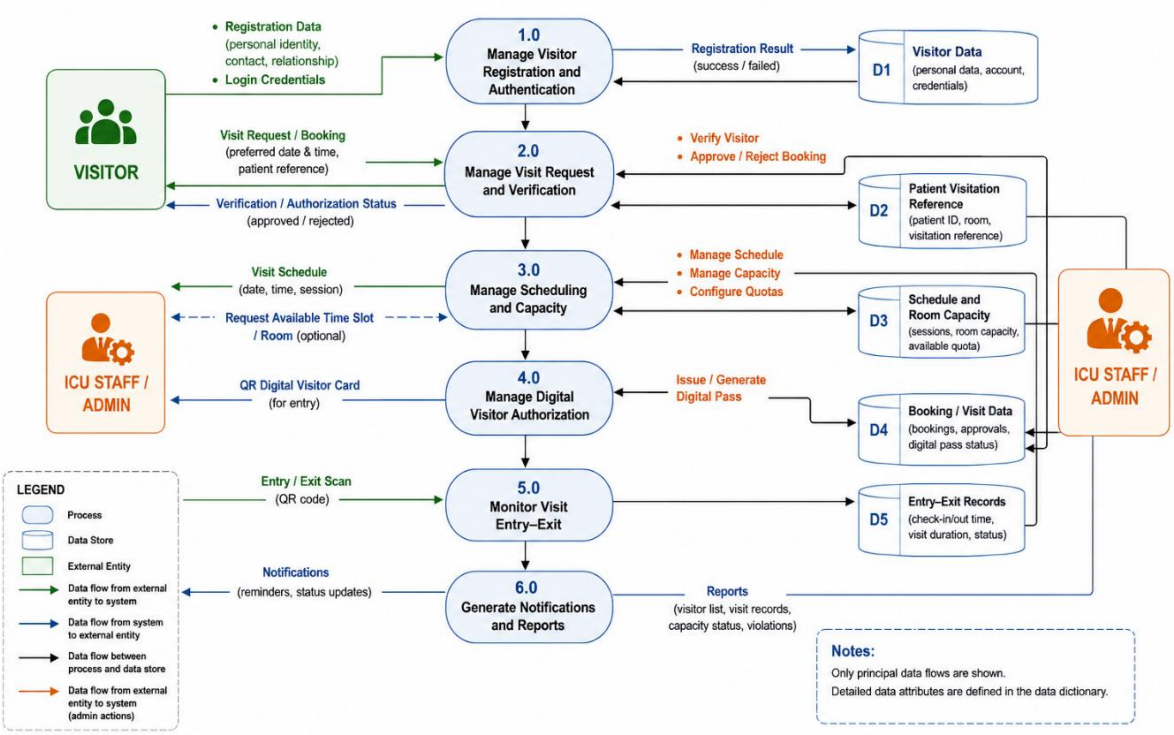


Figure 4. Level 0 data flow graph (DFG) of the digital ICU visitor-management system

3.3. Prototype implementation and technology stack

The prototype was implemented as a web-based application using Apache as the web server and MariaDB as the database management system. Server-side application functions were developed using PHP and the CodeIgniter framework, while Bootstrap supported the web interface implementation. Visual Studio Code was used as the development environment, and Navicat was used for database administration.

3.4. Database and data structure

The prototype database was structured around the information required by the ICU visitation workflow. The principal data groups include visitor information, patient visitation references, visit schedules, building and ICU room information, room capacity, booking records, digital visitor authorization, and visitor entry–exit records. These data support visitor verification, scheduling, capacity checking, access authorization, visit-duration monitoring, and reporting.

Only patient-related information required for visitation management is included within the prototype workflow, such as patient identification, room designation, and visitation status. Clinical and diagnostic information is outside the scope of the prototype.

3.5. Prototype feasibility assessment

Following prototype development, a prototype-level feasibility assessment was conducted to examine the requirements and considerations associated with further implementation. The assessment covered technical, economic, operational, and legal and ethical dimensions. To provide empirical evidence for the operational requirements addressed by the prototype, a questionnaire-based assessment was also conducted. The questionnaire examined two related aspects: patients' perceptions of hospital visitation and the existing practices and perceived needs associated with visitor registration. The visitation component included patients who reported having visitors (N=61) and patients who reported having no visitors (N=177). The visitor-registration component involved 200 respondents and examined the use of conventional visitation procedures, manual recording of visitor information, accessibility of visitor-related information, the use of online registration, and the perceived need for a systematic online visitor-registration mechanism. Responses were summarized descriptively using frequencies and percentages.

The questionnaire was used as supporting evidence for user needs and preliminary operational requirements rather than as a formal usability evaluation of the developed prototype. It did not measure task effectiveness, task efficiency, task completion rate, error frequency, user satisfaction with the implemented

system, or standardized usability scores. Accordingly, the questionnaire findings were interpreted as contextual evidence supporting requirements identification and preliminary operational feasibility. Formal usability validation involving representative ICU visitors, patients' families, healthcare personnel, and administrative staff remains necessary in subsequent evaluation.

The prototype was also compared with conventional ICU visitor-management procedures across several functional aspects, as discussed in the Results and Discussion section. In addition, a SWOT analysis was conducted to identify the strengths, weaknesses, opportunities, and threats associated with the proposed system and its potential implementation in hospital environments.

The assessment was intended to characterize prototype-level implementation feasibility and should not be interpreted as a quantitative usability, clinical effectiveness, or real-world operational performance evaluation. Quantitative usability testing involving representative hospital staff and visitors was outside the scope of the present prototype-level assessment and is reserved for subsequent validation.

Accordingly, the development procedure progressed from requirements identification and conceptual design through prototype implementation and prototype-level feasibility assessment. The resulting functional modules and feasibility findings are presented in section 4.

4. RESULTS AND DISCUSSION

The eight modules implement the visitor-management workflow defined during the requirements and design stages. Rather than functioning as independent interfaces, the modules collectively support the progression from visitor registration and authentication to scheduling, authorization, capacity control, and visit monitoring.

The registration module captures the visitor information required for subsequent verification and visit authorization, see Figure 5. This module establishes the initial visitor record and provides the data required by the subsequent authentication, booking, and authorization processes. The login module provides authenticated access to the prototype, see Figure 6. Separating registration from authenticated access enables subsequent visit requests and booking activities to be associated with an identified visitor account. The dashboard module provides visitors with centralized access to ICU visitation information, including available rooms, visiting schedules, and general visitation requirements, see Figure 7. Its role within the workflow is to consolidate information required before a visitor proceeds to scheduling and booking. The visit schedule module allows visitors to select an available date, session, and time slot, see Figure 8. This function translates the predefined ICU visitation rules into configurable scheduling options and provides the basis for controlling the distribution of visits across available sessions. The room and capacity module presents room availability and configured visitor capacity, see Figure 9. By linking scheduling with room-capacity information, the prototype provides a mechanism for preventing additional bookings when the predefined session quota has been reached. The booking module connects the selected patient visitation reference, room, and visit schedule within a single reservation record, see Figure 10. The resulting booking becomes the basis for staff verification and subsequent visitor authorization. Following authorization, the digital visitor card module generates a visit-specific QR-based credential containing the information required for controlled ICU entry, see Figure 11. The digital pass links visitor identity with the authorized room and visit period without displaying clinical patient information. The visit notification module provides reminders and visit-status information associated with the authorized schedule, see Figure 12. Within the proposed workflow, this function supports communication of visit timing and status without requiring the visitor to rely exclusively on verbal information from hospital staff. Taken together, Figures 5–12 demonstrate the implementation of the proposed end-to-end visitor-management workflow.

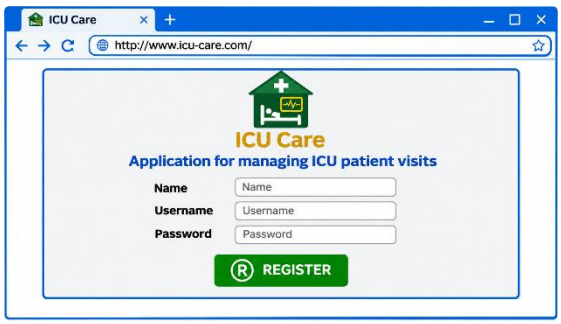


Figure 5. Register module



Figure 6. Login module

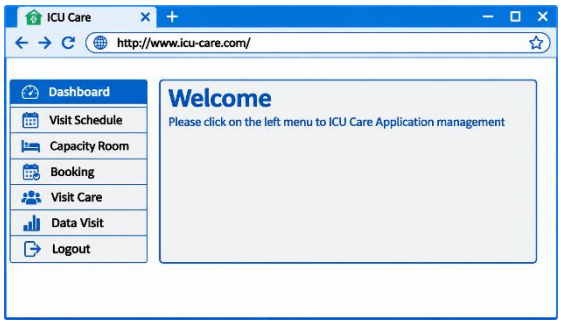


Figure 7. Dashboard module

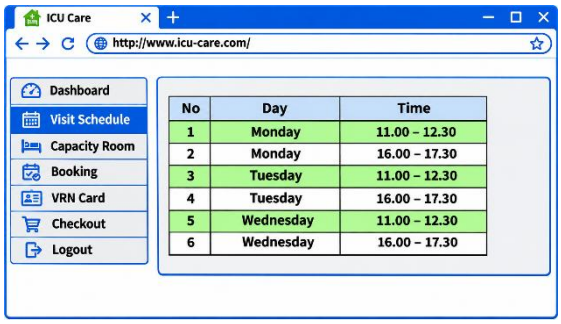


Figure 8. Visit schedule module

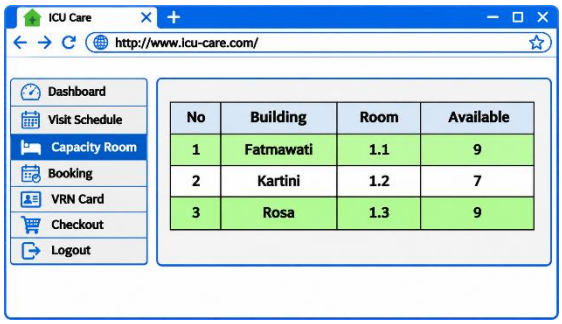


Figure 9. Illustrates the building capacity, rooms, and availability module

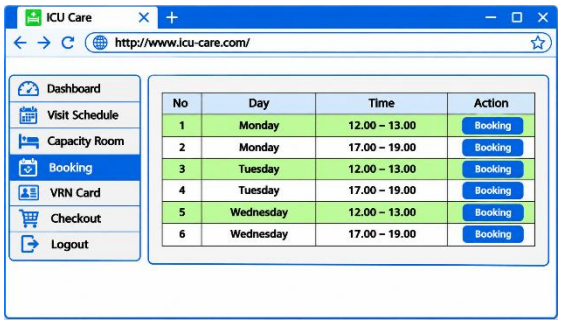


Figure 10. Booking module

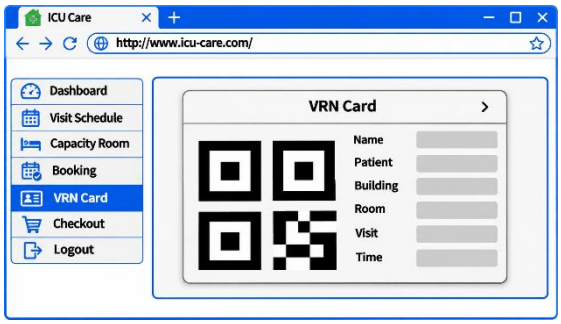


Figure 11. Digital visitor card module

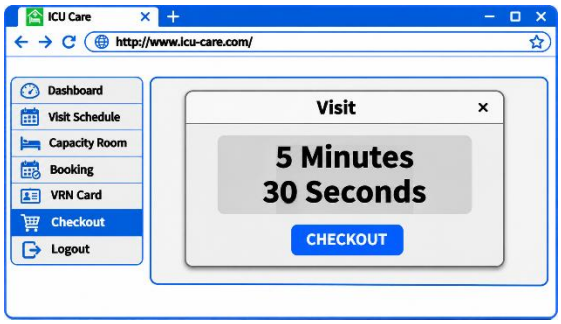


Figure 12. Visit notification module

4.1. User needs and operational requirements

The questionnaire findings provide empirical evidence regarding the operational context addressed by the proposed prototype. Among patients who reported having visitors (N=61), 60 respondents (98%) indicated that visitor presence improved their overall well-being and satisfaction, while 53 respondents (87%) indicated that visitors contributed to supporting their care after discharge. Among patients who reported having no visitors (N=177), 70 respondents (40%) reported that the absence of visitors reduced their overall well-being and satisfaction, while 104 respondents (59%) indicated that their care would have been better if visitors had been permitted. In addition, 83 respondents (47%) reported difficulties for family members or caregivers in obtaining information about the patient's hospital care when visitation was unavailable.

The visitor-registration assessment involving 200 respondents identified several operational gaps. Conventional visitation procedures were reported by 158 respondents (79.0%), while 150 respondents (75.0%) reported that visitor information was still recorded manually. Difficulties in accessing important visitor-related information were reported by 132 respondents (66.0%). Furthermore, 162 respondents (81.0%) indicated that online visitor registration had not yet been used, whereas 178 respondents (89.0%) indicated a need for a systematic online visitor-registration mechanism.

These findings provide empirical support for the functional priorities of the prototype, particularly digital visitor registration, structured visitor records, scheduling, authorization, capacity management, and visitor-information accessibility. However, the questionnaire findings represent perceived needs and existing practices rather than evidence of the usability or operational effectiveness of the developed prototype.

The functional sequence connects visitor registration and authentication with information access, scheduling, capacity management, booking, digital authorization, and visit notification. The principal system contribution at the prototype level is therefore the integration of these functions within a unified ICU-specific workflow rather than the introduction of any single module in isolation.

A summary of the questionnaire findings, including the number and proportion of respondents reporting each identified operational condition, is presented in Table 1. These findings provide an empirical basis for identifying the functional priorities of the proposed ICU visitor-management prototype.

Table 1. Questionnaire-based evidence of visitor-management needs

Assessment item	N	Yes, n (%)
Conventional visitation procedures were still used	200	158 (79.0%)
Visitor information was recorded manually	200	150 (75.0%)
Important visitor-related information was difficult to access	200	132 (66.0%)
Online visitor registration had not yet been used	200	162 (81.0%)
A systematic online visitor-registration mechanism was needed	200	178 (89.0%)

Source: questionnaire-based assessment conducted in the study setting

4.2. Prototype feasibility assessment

From a technical perspective, the prototype demonstrates that the proposed visitor-management workflow can be implemented using a conventional web-application architecture. However, operational deployment would additionally require reliable network connectivity, server availability, backup mechanisms, access control, and technical maintenance. Therefore, the present findings indicate prototype-level technical feasibility rather than production-level system readiness.

From an economic perspective, the use of established web technologies may reduce the need for specialized development infrastructure. Nevertheless, the present study did not conduct a formal cost-effectiveness or return-on-investment analysis. Deployment costs associated with servers, network infrastructure, maintenance, training, security, and integration should therefore be quantified in future implementation studies.

From an operational perspective, the prototype digitalizes several tasks that are conventionally performed manually, including registration, scheduling, authorization, capacity checking, and visit documentation. This functional integration has the potential to reduce repetitive administrative processes; however, its actual effects on staff workload, user acceptance, and workflow efficiency require validation in an operational ICU environment.

The prototype demonstrates preliminary implementation feasibility, subject to further technical and operational validation. The prototype design considers principles of personal data protection by limiting access to authorized users and restricting patient-related information to data required for visitation management. Formal legal and regulatory compliance assessment remains necessary before operational deployment.

Operational deployment would require strengthened security controls, including appropriate authentication, role-based access control, encryption, audit logging, backup mechanisms, and data retention procedures. Overall, the feasibility assessment indicates that the proposed workflow is technically implementable at the prototype level, while also identifying infrastructure, training, security, legal, and operational requirements that must be addressed before real-world deployment. These findings should therefore be interpreted as implementation-readiness considerations rather than evidence of quantitative usability or operational effectiveness.

Table 2 highlights a structural difference between the two approaches. Conventional procedures depend primarily on manual registration, staff-mediated verification, separately communicated schedules, and manual documentation. In contrast, the proposed prototype integrates these functions into a sequential digital workflow. The principal technical advantage is therefore not simply replacing paper records with electronic forms, but linking registration, scheduling, capacity control, authorization, visit monitoring, and reporting through shared visitor and visit records.

This integration also introduces trade-offs. The digital approach depends on network and server availability, user familiarity with digital services, staff training, and appropriate security controls. Conventional procedures may remain easier to operate during infrastructure failures or exceptional situations. Consequently, digital visitor management should complement hospital contingency procedures rather than eliminate the need for alternative access mechanisms.

Table 2. Conceptual functional comparison between conventional ICU visiting procedures and the proposed digital prototype

Aspects	Conventional ICU visiting procedure	Proposed digital prototype
Visitor registration	Typically performed manually by ICU staff using visitor records or books.	The process is conducted online (via web/app) or through a digital lobby at the hospital with integrated data.
Identity verification	Identity verification depends on the applicable manual hospital procedure and may not be integrated with digital visitation records. Data duplication or unidentified visitors may arise.	Registration records official identification details (e.g., KTP/SIM), which are reviewed by authorized hospital personnel before visitation approval.
Visiting schedule	Visiting schedules are typically communicated verbally or displayed on information boards or websites. Visitors may arrive without a prior reservation.	The timetable is established periodically and has restricted capacity, with booking slots requiring officer approval.
Visitor limits	The situation is difficult to control, as many visitors often come for one patient at a time.	The system is systematically restricted based on the ICU's capacity, allowing a maximum of one visitor per patient per session.
Visiting duration	Visitor-duration monitoring may depend on manual supervision and may not be supported by systematic digital recording of entry and exit times. Visitors can exceed the time limit (30 minutes).	The system manages and monitors clock-in/clock-out times, with automatic notifications and digital records.
Visitor card	Not available.	This is a unique QR code-based digital card, valid only for specific times and visitors.
Patient data access	Limited access to staff can only be requested directly. These restrictions can be confusing at times.	Non-medical patient data, such as name, room, and visit status, is limited to the online system.
Security and privacy	Visitor access is generally managed through staff-mediated procedures and manual records, without an integrated digital workflow in the study setting.	Designed to support controlled access to visitor information and recorded visit history; production deployment requires validated encryption, access-control, and security mechanisms.
Room capacity monitoring	This is done manually by staff, not in real time. Overcapacity can occur.	The prototype checks configured room/session capacity and can prevent additional bookings when the predefined visitor quota has been reached.
Operational efficiency	This burdens ICU staff with record-keeping, scheduling, and access control.	Digitalizes scheduling, validation, and monitoring functions that otherwise require manual processing; the effect on staff workload requires operational evaluation.
Reporting and evaluation	Documentation and reporting depend on manual records and may require additional staff effort for compilation and review.	Daily/weekly reports, visitor statistics, violations, and visit history are available.

Visitor access is generally managed through staff-mediated procedures and manual records, without an integrated digital workflow in the study setting.

4.3. Strengths, weaknesses, opportunities, and threats analysis and implementation implications

4.3.1. Strengths

The integration of registration, scheduling, authorization, capacity monitoring, and visit records reduces reliance on disconnected manual processes. This represents a functional strength of the prototype, although actual time and human-resource savings require operational measurement. The visitor-verification and visit-specific authorization functions provide a technical mechanism for strengthening visitor traceability and access control. Configured room capacity and visit-duration rules can be incorporated into scheduling and monitoring functions, allowing visitation policies to be represented directly within the system workflow. Structured visit records may provide a basis for subsequent reporting and evaluation of visitation patterns, subject to appropriate privacy and data-governance controls.

4.3.2. Weaknesses

A principal implementation constraint is dependence on reliable network connectivity, server infrastructure, user devices, and system maintenance. Implementation would require training for ICU staff and appropriate guidance for visitors, particularly users with limited familiarity with digital services. The stand-alone prototype does not currently exchange data with an operational HIS. Interoperability should therefore be addressed as a subsequent development stage rather than treated as an existing system capability.

4.3.3. Opportunities

The modular workflow may be adaptable to non-ICU inpatient units, although different visitation policies and operational requirements would require additional validation. Future development may investigate secure interoperability with existing HIS platforms to reduce duplicate data entry and synchronize authorized patient-location, room, and visitation-status information. Structured visitor documentation and access-

management processes may support broader hospital service-quality and governance objectives; however, accreditation effects were not evaluated in this study.

4.3.4. Threats

Server outages and network disruptions could interrupt registration, authorization, and QR-based access processes; therefore, production deployment would require availability monitoring, backup procedures, and contingency workflows. Differences in digital literacy may affect adoption, particularly among visitors unfamiliar with online registration or QR-based access. Alternative assistance mechanisms should therefore be considered during deployment. Because the system processes personally identifiable visitor information and limited patient-related visitation data, cybersecurity and privacy risks must be addressed through validated authentication, authorization, encryption, audit logging, secure backup, and data-governance procedures before operational deployment.

4.4. Technical contribution of the prototype

The principal technical contribution of the proposed prototype is the integration of multiple ICU visitor-management functions within a single workflow. Registration, authentication, scheduling, room-capacity control, booking, digital visitor authorization, entry–exit monitoring, notification, and reporting are represented as connected processes rather than independent administrative activities. This design enables visitation rules—such as authorized time periods, visitor quotas, and visit duration—to be translated into system-level controls. Accordingly, the contribution lies primarily in workflow integration and prototype implementation for ICU visitor management rather than in the introduction of an entirely new individual software function.

4.5. Comparison with previous digital hospital approaches

The proposed system shares the broader digitalization objective reported in previous studies of HIS, web-based patient-management platforms, and hospital management interfaces [20]-[22]. These studies demonstrate how information technology can support the organization, accessibility, and management of healthcare-related information.

The questionnaire findings provide an additional empirical perspective on the operational problem addressed by the prototype. The predominance of conventional visitation procedures (79.0%) and manual visitor-data recording (75.0%) suggests that visitor management may remain dependent on fragmented administrative practices in the study context. The finding that 66.0% of respondents experienced difficulty accessing important visitor-related information further indicates an information-management gap. Most notably, 89.0% of respondents expressed a need for systematic online visitor registration. This finding supports the decision to prioritize digital registration and structured visitor records within the proposed workflow. Nevertheless, the result should be interpreted as evidence of perceived operational need rather than evidence of user acceptance or demonstrated improvement in system performance.

However, the present prototype addresses a narrower operational problem: ICU visitor management. Rather than focusing primarily on clinical records or general hospital administration, the proposed system organizes visitor-related processes including registration, scheduling, authorization, room-capacity management, visit-duration monitoring, and visit documentation.

Previous research has examined patient- and family-centered care in ICU environments, information needs among families of critically ill patients, organizational implementation of HIS, and mobile workflow applications in healthcare institutions [20], [21], [23], [24]. These studies provide relevant perspectives on healthcare information management and digital workflow implementation. However, they do not directly address the integration of ICU-specific visitor registration, identity verification, scheduling, capacity control, digital authorization, and visit monitoring within a unified visitor-management system. The present study extends this digital-service perspective to ICU visitation by translating visitation requirements into an integrated visitor-management workflow. Nevertheless, direct performance superiority over existing HIS cannot be inferred because no head-to-head quantitative system evaluation was conducted.

4.6. Practical implementation considerations

For hospital implementation, the prototype suggests that visitation policies can be operationalized through configurable scheduling, capacity, authorization, and monitoring functions. This may support more consistent visitor-management procedures and improve the traceability of visit activities. However, implementation would require alignment with existing ICU workflows, staff responsibilities, emergency-access procedures, visitor assistance mechanisms, and hospital data-governance policies [25].

Scalability should also be considered before broader deployment. Increasing the number of users, rooms, simultaneous bookings, and entry–exit transactions may affect server load, database performance, and system availability. Because load, concurrency, response-time, and stress testing were not conducted in the

present study, the scalability of the prototype remains to be established through dedicated performance evaluation.

The current prototype was intentionally evaluated as a stand-alone visitor-management application and is not presented as being integrated with an operational HIS. Future work should examine interoperability through secure interfaces or application programming interfaces (APIs), particularly for authorized exchange of patient visitation references, room information, and visitation status. HIS integration should therefore be regarded as a future development direction rather than evidence of a failure of the present prototype.

Technology adoption also depends on factors beyond system functionality. Staff acceptance, visitor digital literacy, workflow disruption during transition, privacy expectations, and availability of technical support may influence real-world use. A phased pilot implementation with user training and assisted registration would therefore be more appropriate than immediate large-scale deployment.

Overall, the results demonstrate the functional implementation and preliminary feasibility of the proposed ICU visitor-management workflow. They do not, however, establish quantitative usability, clinical effectiveness, workload reduction, cybersecurity effectiveness, or production-level performance. These outcomes require dedicated validation in subsequent operational studies.

4.7. Study limitations

This study has several limitations. First, the developed system remains a functional prototype and has not yet been deployed as part of routine ICU operations. Consequently, the findings represent prototype-level development and feasibility assessment rather than evidence of long-term operational effectiveness. Second, the present study did not conduct large-scale quantitative usability testing involving representative groups of ICU staff, hospital administrators, and visitors.

The questionnaire-based assessment also has limitations. The questionnaire was descriptive and focused on perceived needs and existing visitation practices rather than standardized usability, technology acceptance, or behavioral-intention constructs. In addition, the available questionnaire documentation does not establish population-level representativeness; therefore, the reported percentages should be interpreted as contextual evidence from the study setting rather than generalizable estimates for hospitals or ICU populations.

Therefore, user acceptance, perceived usability, task-completion performance, and user experience cannot yet be quantitatively established from the present findings. Third, dedicated system-performance testing, including response-time, concurrent-user, load, stress, and availability testing, was outside the scope of the present prototype assessment. The scalability and production-level performance of the system therefore remain to be evaluated.

Fourth, although privacy and security requirements were considered in the system design, the prototype has not undergone dedicated cybersecurity testing. Authentication security, authorization controls, encryption, vulnerability assessment, audit logging, backup, and recovery mechanisms require further technical validation before operational deployment. Fifth, the current prototype operates as a stand-alone visitor-management application and has not yet been integrated with an operational HIS. HIS interoperability is considered a subsequent development stage and will require secure mechanisms for exchanging only the patient, room, and visitation information authorized for visitor-management purposes. Finally, the present feasibility assessment does not evaluate clinical outcomes or establish whether use of the system improves patient safety, patient outcomes, family satisfaction, or healthcare-worker well-being. Such outcomes would require separate prospective evaluation in operational hospital environments.

These limitations indicate that the current findings should be interpreted as evidence of functional prototype development and preliminary implementation feasibility. Quantitative usability, performance, security, interoperability, and real-world operational evaluations are required before conclusions can be drawn regarding broader implementation effectiveness.

The need for continued evaluation is also consistent with research examining the temporal degradation of predictive models in healthcare information systems, which demonstrates that performance should be assessed beyond initial model validation and under changing operational conditions [17]. At the broader hospital-operations level, simulation-based analytics has also been investigated as an approach to examining system-level operational scenarios and resource requirements [9]. Although these studies address different healthcare applications, they reinforce the importance of evaluating digital healthcare solutions beyond their initial development stage.

5. CONCLUSION

This study developed a web-based digital ICU patient visiting prototype using the RAD approach. The resulting system integrates visitor registration and authentication, visit scheduling, room-capacity management, booking, QR-based digital visitor authorization, visit-duration monitoring, notifications, and

reporting within a unified visitor-management workflow. The principal technical contribution of the prototype is the integration of these visitor-management functions into a structured ICU-specific workflow, allowing visitation requirements such as scheduling, visitor quotas, authorization, and visit duration to be represented as system-level processes.

The prototype-level feasibility assessment indicates that the proposed workflow is technically implementable using established web technologies, while further implementation requires adequate network and server infrastructure, user training, privacy protection, cybersecurity controls, and alignment with hospital operational procedures. Compared with conventional visitor-management procedures, the proposed prototype provides more structured mechanisms for visitor registration, identity verification, scheduling, capacity control, access authorization, visit documentation, and reporting. However, the present study does not establish quantitative improvements in operational efficiency, staff workload, user satisfaction, or patient outcomes because these aspects were not evaluated in an operational ICU environment.

Future work should include quantitative usability testing with ICU staff and visitors, system-performance evaluation under concurrent-user and load conditions, dedicated cybersecurity and privacy assessment, and pilot deployment in operational ICU environments. Subsequent development should also investigate secure interoperability with existing HIS through controlled interfaces or APIs, particularly for authorized exchange of patient visitation references, room information, and visitation status. Pilot deployment should subsequently evaluate user acceptance, task completion, workflow impact, system reliability, visitor-management efficiency, and scalability before broader hospital implementation is considered.

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AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
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Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

The researchers conducting this investigation declare that no personal or financial conflicts of interest influenced the findings.

INFORMED CONSENT

Written informed consent was obtained from all individual participants included in this study.

ETHICAL APPROVAL

This study involving human participants for prototype feasibility assessment was conducted in compliance with applicable national regulations and institutional ethical guidelines. All procedures were carried out in accordance with the ethical standards of the Declaration of Helsinki. Ethical approval was obtained from the authors' Institutional Review Board (IRB) or equivalent ethics committee prior to data collection.

DATA AVAILABILITY

The data supporting the findings of this study are available from the corresponding author upon reasonable request, subject to applicable ethical requirements and restrictions concerning participant confidentiality and privacy.

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