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A Novel Mobile-Based Blood Donation Model For Emergency Situations

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Abstract
Blood donation is essential to modern healthcare, yet shortages and delays in accessing compatible blood remain a global challenge, particularly in low and middle income countries. In emergency contexts such as trauma, obstetric complications, accidents, surgical crises etc, the absence of timely blood transfusion often results in preventable mortality. Traditional donor mobilization strategies, including static registries and manual blood bank processes, are limited by inefficiencies, lack of real-time updates and weak integration with hospital workflows. This study titled a novel mobile-based blood donation model for emergency situations designed to address these limitations. The application incorporates a real-time geo-location services, automated eligibility screening, and secure communication between hospitals, donors and blood banks. By streamlining donor–recipient matching and ensuring data privacy, the system reduces delays and enhances reliability in emergency transfusion support. Also the application seeks to promote sustained donor participation and foster a community-driven culture of regular blood donation by incorporating some educative features. This model runs on Windows 10 or later, with HTML5, CSS3, and Bootstrap for the front-end, ASP.NET with C# for the back-end, and SQL Server for database management. It is hosted on IIS, developed in Visual Studio, and enhanced with JavaScript, JQuery, and ASP.NET Identity for interactivity and security.The findings highlight the potential of mobile health technology to strengthen healthcare resilience, reduce preventable deaths, and improve emergency medical response.

Keywords: Blood Donation, Emergency Healthcare, Donor–Recipient Matching, Geo-location and Blood Bank.

1. Introduction

Blood transfusion is a cornerstone of modern healthcare, often making the difference between life and death in cases such as trauma, obstetric emergencies, surgical procedures, and chronic illnesses like sickle cell disease. Yet, despite its lifesaving importance, many health systems particularly in low- and middle-income countries struggle with persistent shortages and delays in securing compatible blood. In emergencies where every minute counts, families and hospitals are too often confronted with the devastating reality that suitable blood cannot be sourced quickly enough, turning otherwise treatable conditions into preventable deaths [1]. The safety and success of transfusion hinge on two key systems: the ABO blood group system (A, B, AB, and O) and the Rhesus (Rh) factor (positive or negative). Mismatched transfusions can trigger life-threatening immune reactions, making compatibility critical. In urgent scenarios such as road accidents, complicated childbirth, or major surgeries, the immediate availability of the right blood type is frequently the single most important factor in survival [2].

Traditional approaches to donor mobilization, such as static registries and manual blood bank operations, remain inadequate to meet the fast-paced demands of emergency care. These systems are often slow, fragmented, and poorly integrated into hospital workflows, resulting in delays that cost lives [3, 4]. While blood donation drives and digital platforms exist, they often fall short by failing to provide real-time donor availability, automated eligibility checks, or secure and reliable communication channels between hospitals, donors, and blood banks. Sustaining donor participation is another persistent challenge, as most existing systems do not prioritize engagement, motivation, or feedback mechanisms that encourage long-term commitment [5].

The rapid adoption of mobile technology offers a transformative opportunity to address these limitations. With smartphones now widespread and mobile applications already proving successful in other areas of healthcare delivery, there is strong potential to bridge the gap between urgent hospital needs and donors' willingness to help [6]. A mobile-based application purposefully designed for emergency blood donation could enable real-time matching between patients and nearby eligible donors, integrate geo-location and eligibility screening, and streamline hospital request workflows. By offering secure communication and protecting donor privacy, such a system could not only reduce delays but also build trust and confidence among users [7].

This study responds to that urgent need by developing a novel mobile-based blood donation model for emergency situations. Beyond its technical innovations, the system seeks to foster a more resilient, community-driven culture of donation one where individuals are empowered to act not only in moments of crisis but also as consistent contributors to strengthening healthcare systems. In this way, mobile technology is positioned not merely as a tool but as a lifeline connecting generosity with urgent medical need and transforming the way societies respond to critical health emergencies [8].

2. Review of Related Literatures

Blood groups are central to transfusion medicine, as they determine the compatibility between blood donors and recipients. The ABO blood group system remains the most clinically significant, classifying individuals into groups A, B, AB, and O, based on the presence or absence of surface antigens on red blood cells. In addition, the Rhesus (Rh) factor further refines this classification, designating each blood type as either positive or negative [9]. Together, these systems form the foundation of safe transfusion practices, since incompatibility can lead to severe and potentially life-threatening immune reactions.

As noted by [10], blood donation is the voluntary provision of blood for medical use and remains indispensable in healthcare delivery. Donated blood and its components, including red cells, plasma, and platelets, are vital in trauma care, surgical operations, obstetric emergencies, and the management of chronic conditions such as cancer and severe anemia. Since blood cannot be artificially manufactured, the sustainability of supply relies entirely on the generosity and commitment of voluntary donors [11]. Promoting awareness of blood group systems and encouraging regular donation are therefore crucial steps in strengthening healthcare systems, reducing mortality, and building resilience in both emergency and routine medical care.

Several researchers have explored the role of digital technologies in supporting blood donation. In the work of [12], they developed an online blood donation system aimed at addressing shortages by directly connecting donors with recipients through a user-friendly platform. The system's main goal was to ensure timely availability of blood, particularly in emergencies. Similarly, [13] designed a mobile application to raise awareness and encourage consistent donations. Their study, which applied qualitative methods to better understand donor characteristics and barriers, highlighted useful features such as donation scheduling, real-time information on requirements, and connections to nearby blood banks. However, challenges such as misconceptions about health risks and limited user adoption were noted [14].

In another effort, [15] introduced an Android-based application prototype to address low donor participation rates. Their system provided functionalities including blood bank directories, request postings, and location-based donor–recipient matching. Yet, as [16] observed, motivating individuals to donate via the app was constrained by cultural barriers and low awareness.

It was further opined by [17] the importance of streamlining donor management systems to enhance efficiency. Their work demonstrated reduced response times for locating donors and improved donation rates, largely due to effective notifications and user engagement. Nonetheless, technical glitches, skepticism about mobile systems, and the need for robust security remained challenges [18]. Users consistently ranked

features such as donor center locators, blood-type specific requests, and automated reminders as essential for successful adoption.

Other approaches include the development of web and cloud based systems [19] built to automate donor registration, blood inventory, and request processing. Their system increased operational efficiency, improved inventory control, and reduced the time required to match donors with recipients. Likewise, [20] explored a cloud-based system to provide scalable, real-time communication between donors, recipients, and hospitals. Despite its promise, accessibility issues particularly among users with limited digital literacy were highlighted. Qualitative feedback recommended expanding features such as social media integration for outreach and assistive tools for visually impaired users [21].

User adoption, as [22] pointed out, is strongly influenced by perceived usefulness, peer influence, and digital habits. Patients tend to prefer personalized features such as location-based matching, timely notifications, and simplified scheduling. In the work of [23] it was further argued for the integration of social media to build donor communities, while [24] emphasized that sustained use of donation apps requires strong privacy protections, thoughtful design, and engaging user experiences. Younger generations show particular interest in these innovations, suggesting that well-designed mobile and web-based systems can significantly strengthen blood donation networks.

Collectively, these studies demonstrate that while technological solutions hold great potential to improve blood donation practices, their success depends on user trust, accessibility, and meaningful engagement. For healthcare systems and developers, these insights underscore the importance of designing inclusive, secure, and community-driven platforms to ensure blood is always available when needed most.

3. Methodology and System Design

3.1 Choice of Methodology

This system was developed using the Object-Oriented Methodology (OOM), which models real-world entities as interacting objects. This approach makes the design intuitive, modular, and easy to maintain, ensuring the system remains reliable, scalable, and adaptable to future needs.

3.2 Method of Data Collection

A mixed-methods approach was adopted to evaluate both the technical performance and user experiences of the mobile blood donation application. System logs offered objective data on request initiation, donor notifications, response rates, and time-to-donation, while structured questionnaires captured feedback on usability, motivations, and challenges. To gain deeper insights, semi-structured interviews, focus groups, and hospital observations were conducted, complemented by a review of de-identified clinical records for validation. Ethical standards such as informed consent, anonymity, and secure data handling were strictly upheld to ensure credibility and protect participants.

3.3 Analysis of the System

This model, a novel mobile-based blood donation model for emergency situations is designed to revolutionize how donor information and blood inventory are managed in medical facilities. The platform automates key processes, from donor registration and profile management to blood tracking and stock monitoring, reducing paperwork and minimizing errors. Donors can easily register, update their health details, and receive automated notifications about donation eligibility, while hospital staff can quickly search for compatible donors by blood type and location to ensure timely availability in emergencies. The system also provides real-time reports and alerts on inventory levels, supporting better planning for donation drives and preventing shortages. With secure login and role-based access, sensitive data remains protected and restricted to authorized users. By streamlining communication, improving efficiency, and strengthening responsiveness, the application enhances the overall management of blood donation and contributes to better patient care outcomes.

3.4 The Model's algorithms

1. ***Auth & Profile****: secure registration/login for donors, hospitals, blood banks, admins. Stores blood type, donation history, health notes, contact, verification status.*
2. ***Eligibility Engine****: enforces blood donation rules (age, interval since last donation, health flags).*
3. ***Request Manager****: hospital creates an emergency request (blood type, units, urgency, location).*

4. ***Matching & Prioritization****: ranks eligible donors by compatibility, proximity, availability score and response reliability.*
5. ***Notification Dispatcher****: pushes alerts (SMS/Push) and handles acknowledgements.*
6. ***Verification & Logistics****: verifies donor identity (OTP/ID), schedules collection, maps route to collection site, and updates hospital/blood bank inventory.*
7. ***Audit & Analytics****: logs events, measures response times, donor engagement metrics.*
8. ***Security & Privacy****: encryption, data minimization, consent logs, role-based access.*

The model's Data Structure Outlines

1. *User { id, name, phone, blood_type, last_donation_date, eligibility_status, location (lat,lon), availability_status, response_score }*
2. *HospitalRequest { id, hospital_id, blood_type_needed, units_needed, urgency, location, created_at, status }*
3. *MatchCandidate { user_id, distance_km, compatibility_score, availability_score, overall_priority }*
4. *DonationEvent { id, request_id, donor_id, verified, collected_at, units_collected }*

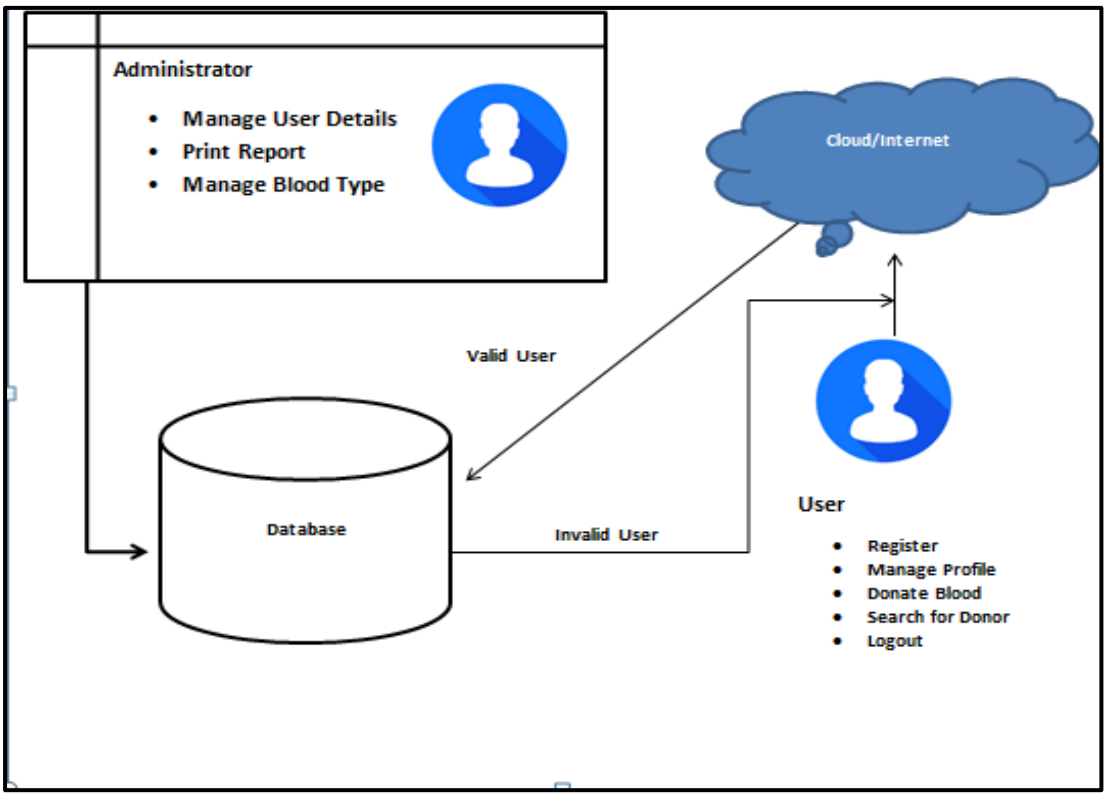

Figure 1: The model's architecture

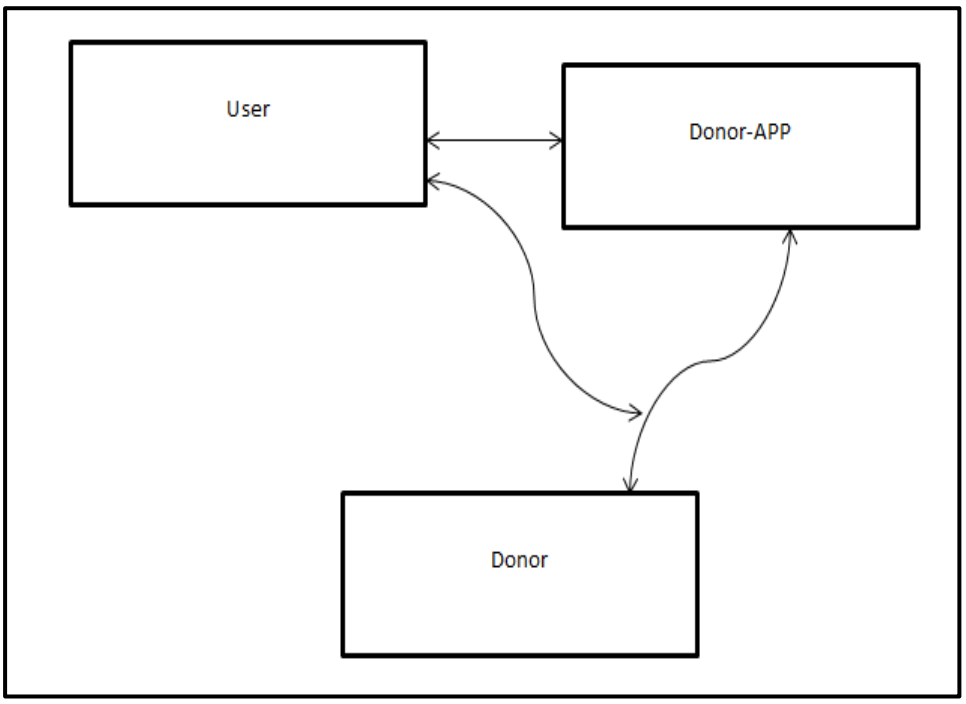

Figure .2: High Level diagram of the model

3.5 System Design

The system design begins with a clear overview of its purpose: to overcome the challenges of manual blood donation processes by automating and streamlining operations. The platform provides donors with a simple way to register, check available blood types, and receive notifications for urgent requests, while hospital staff can efficiently manage inventory, track donation schedules, and communicate directly with donors. This not only reduces delays and paperwork but also ensures a better match between supply and demand. Key inputs to the design include donor details (name, blood type, contact information), blood inventory records, donation requests, and hospital needs. These are collected through user-friendly registration forms and staff data entry interfaces, supplemented by real-time notifications and location services that connect donors with the nearest hospitals or blood banks in need.

3.6 Data Flow Diagram

The Level 1 Data Flow Diagram (DFD) of a novel mobile-based blood donation model for emergency situations outlines how the platform functions through four key processes: donor profile management, donation tracking, inventory control, and report generation. These processes interact seamlessly with external users, donors, hospital staff, and administrators while drawing from internal data stores such as donor records, donation logs, and inventory databases with the following processes.

Register and Manage Donor Profile (1.0): This enables donors to input and update personal, health, and contact details, which are stored in the Donor Database for verification and eligibility checks. Hospital staff may also assist with managing this data, while the system sends automated reminders to donors when they become eligible to donate again.

Record and Track Blood Donation (2.0) allows staff to log donation activities, validate donor eligibility, and store details in the Blood Donation Records database, ensuring accurate tracking of donations.

Manage Blood Inventory (3.0): It updates stock levels automatically after each donation, reflecting real-time availability by blood type and quantity, with options for manual updates by administrators.

Generate Reports and Notifications (4.0) Tis is the finally stage and it compiles data into summaries and real-time alerts that guide decision-making, such as organizing donation drives or addressing shortages, while also sending personalized notifications to donors to keep them engaged and informed.

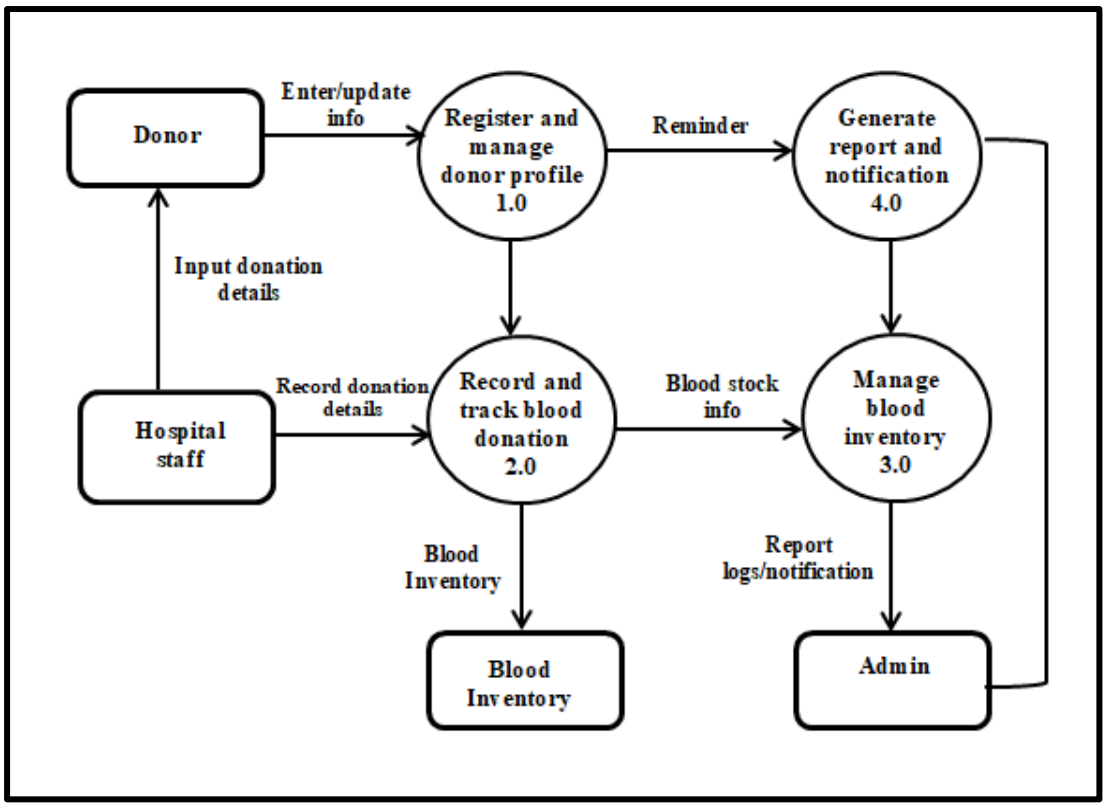

Figure 3: Level 1 DFD of the model

3.7 Component/Main Menu Design

The Component and Main Menu Design of model was carefully structured to provide a simple, intuitive and role-based interface for donors, hospital staff, and administrators. Each user group has access only to the tools relevant to their responsibilities, which improves usability, streamlines operations, and ensures data security across the system. They are as follows;

Dashboard: At the center of the application is the personalized landing page known as the dashboard that gives users an at-a-glance overview of key activities. For donors, this might include eligibility status and donation history, while hospital staff and administrators may see daily donation counts, low-stock alerts, or reminders about pending verifications.

Donor Management module: This simplifies the registration of new donors and the updating of existing profiles. Staff can edit health records, verify eligibility, and use the built-in search tool to quickly identify donors by blood type or location an essential feature in time-sensitive emergencies.

Blood Donation Management module: This module ensures that every donation is accurately recorded, tracks donor histories, and supports compliance with medical guidelines. It also includes tools for generating statistics and identifying donation trends over time.

Blood Inventory module: It offers real-time visibility of stock levels, categorizing blood units by type and status (available, used, or expired). Staff can set up alerts to flag shortages, helping hospitals maintain adequate supplies and plan donation drives before shortages occur. **Notification Center**: This interface manages all system communications. Donors receive reminders about upcoming eligibility, while staff and administrators are notified about urgent stock updates. Preferences can be customized, and all communications are logged for accountability.

Report Generation module: It handles oversight and strategic planning of the model. This allows users to create and export detailed reports, such as donor lists, usage statistics, or inventory summaries, in formats like PDF and Excel.

User Management module: This is accessible only to administrators, safeguards system security by enabling account creation, role assignment, access control, and monitoring of login activities.

Settings section: It allows users to tailor system behavior by configuring hospital details, database options, backups, and notification preferences. A secure Logout function ensures that every session ends safely, preventing unauthorized access once the user leaves the system. Together, these components create a user-

friendly and secure environment that enhances communication, boosts efficiency, and strengthens the overall management of blood donation activities.

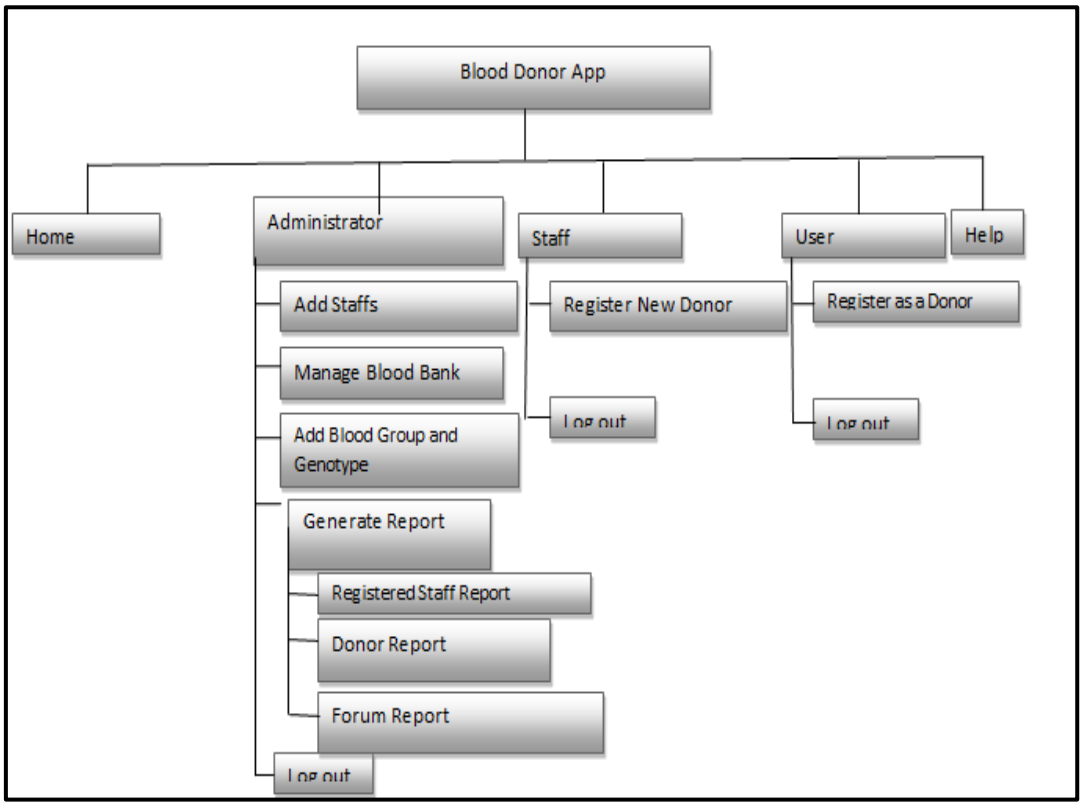

Figure 4: Component/menu diagram of the model

3.8 Software and Hardware Specification

The development of a novel mobile-based blood donation model for emergency situations requires well-defined software and hardware specifications to ensure efficiency, reliability, and compatibility across different environments. On the software side, the system is built using Windows 10 or later as the operating system, with HTML5, CSS3, and Bootstrap for the front-end, and ASP.NET with C# for the back-end. SQL Server manages the database, while IIS hosts the web application, and Visual Studio serves as the IDE, supported by JavaScript, JQuery, and ASP.NET Identity for interactivity and security. For hardware, the system is optimized to run on standard configurations, with a minimum of Intel Core i3 processor, 4 GB RAM, and 100 GB HDD, while higher performance is recommended with Intel Core i5, 8 GB RAM, and a 256 GB SSD. Additional requirements include a 15.6" HD display or larger, internet connectivity for database access, and peripherals such as a keyboard, mouse, and optional barcode scanner or RFID reader for hospital integration.

3.9 UIX Implementation

The UI/UX of the Blood Donation Management System was designed to be simple, intuitive, and accessible for both technical and non-technical users. Built with HTML5, CSS3, and Bootstrap 4.5, the responsive layout works seamlessly across desktops, laptops, tablets, and smartphones. JavaScript and jQuery enhance interactivity by enabling real-time feedback, smooth navigation, and fewer page reloads, while streamlined forms with drop-downs and date pickers make data entry quick, accurate, and user-friendly for donors, hospitals, and administrators alike.

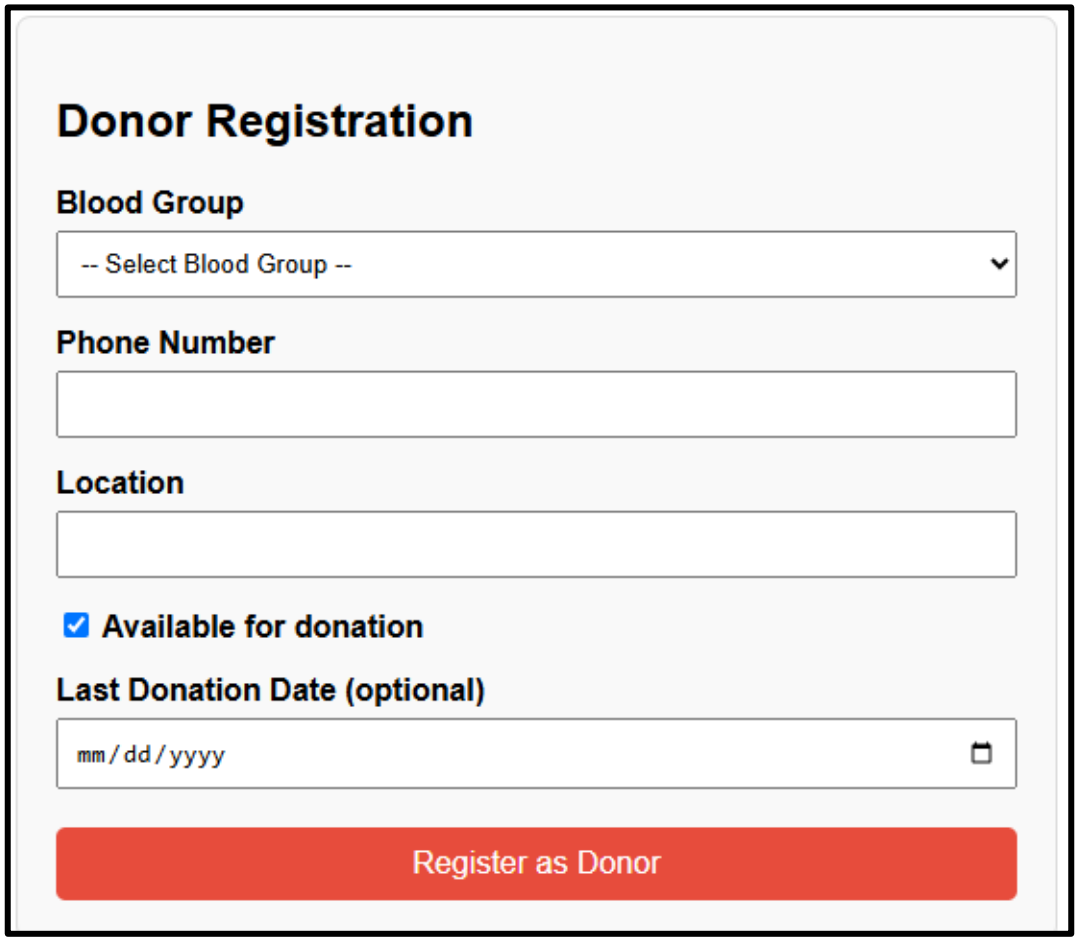

Figure 5: Donor registration page

Blood Request Interface: Allows hospitals or individuals to request specific blood types and view matching donor availability.

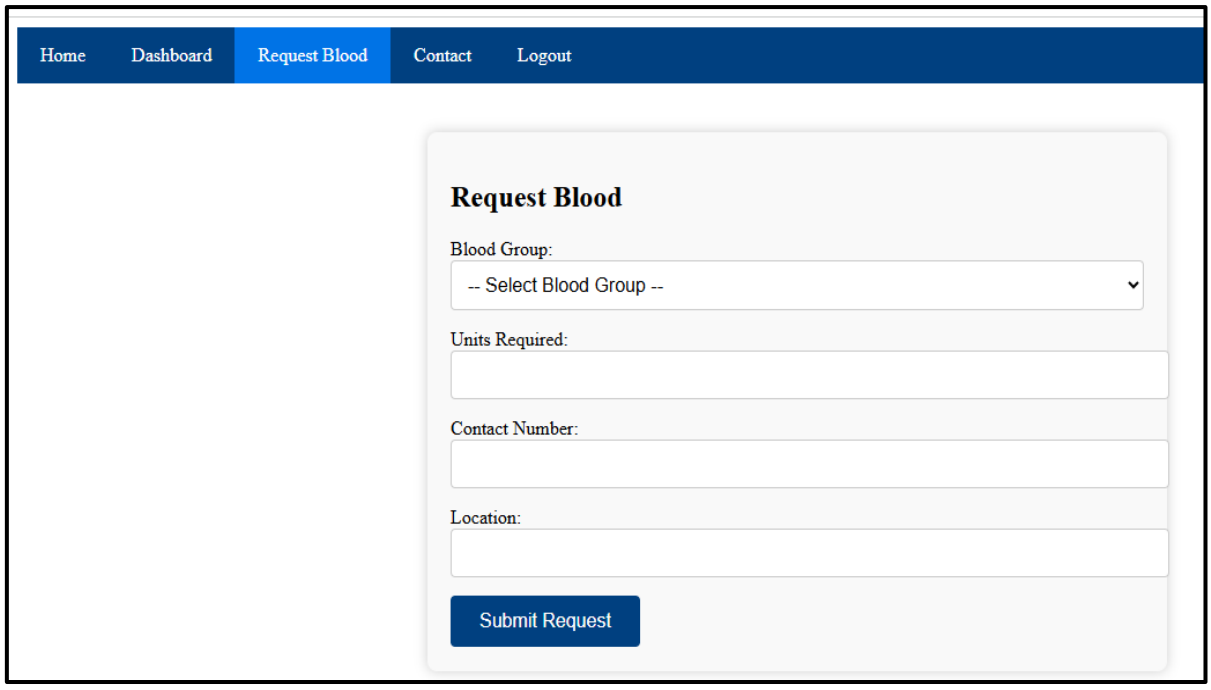

Figure 6: Blood request page

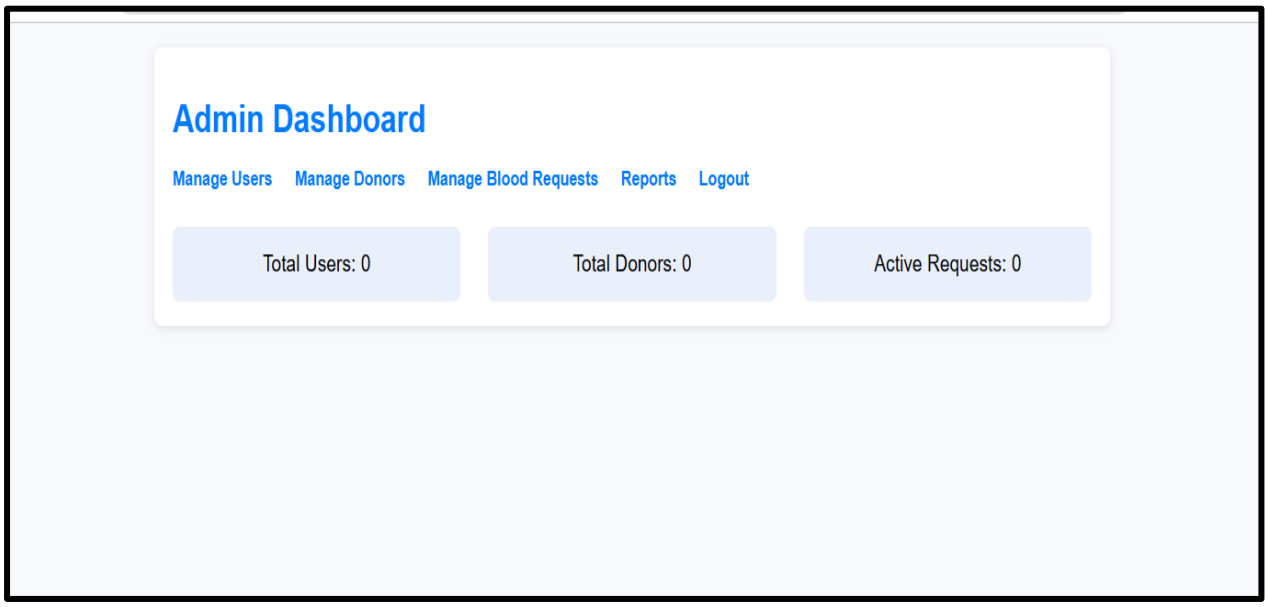

Figure 7: Admin Dashboard

Admin Dashboard: Equipped with summary statistics, charts, and management tools for donor records, blood inventory, and request history.

3.10 Database Implementation

The database for the Blood Donation Management System was implemented using Microsoft SQL Server, selected for its reliability, scalability, and ability to handle complex data relationships. It provides a secure and organized framework for managing donor and recipient records, blood inventory, and transactional data. The schema was carefully designed to support the system's core functions, ensuring data integrity, reducing redundancy, and enabling fast, efficient queries. To achieve this, normalization principles were applied up to the third normal form (3NF), helping to minimize duplication while maintaining strong relational consistency.

3.11 Security Model Implementation

Ensuring security was a top priority in developing the Blood Donation Management System, as it handles sensitive health data that demands strict privacy and protection. To safeguard user information and maintain system integrity, a layered security framework was implemented. Access is controlled through strong authentication processes, where users must log in with valid credentials. Passwords are never stored in plain text but are securely hashed and salted using algorithms like SHA-256 or BCrypt, significantly reducing the risk of exposure even if the database is compromised.

4. Analysis and Discussion of Findings

After the system was fully deployed, its performance was carefully evaluated across several dimensions, including usability, responsiveness, donor engagement, accuracy of donor-recipient matching, and hospital inventory management. The results demonstrated a significant leap in efficiency, with the average time for donor-recipient matching reduced from the manual range of 1–3 hours to less than 20 minutes. This was largely achieved through the integration of GPS-enabled donor location services and an advanced search feature, both of which simplified and accelerated the emergency response process. The streamlined design not only saved time but also increased reliability in critical situations where rapid access to blood donors is vital.

User feedback further emphasized the system's impact. Out of 100 surveyed participants, 92% found the platform intuitive, responsive, and easy to navigate, with both donors and hospital staff highlighting its simplicity compared to traditional systems. Donors expressed particular appreciation for the SMS and email notification features, which reminded them of upcoming donations and alerted them to urgent requests. This proactive engagement contributed to a 34% rise in repeat donations within just the first month of deployment, showing the system's effectiveness in fostering a consistent donor community. Hospitals also

reported greater control over blood stock levels, with the real-time dashboard enabling precise monitoring of blood types and quantities, thereby minimizing shortages and reducing waste from expired units.
Finally, the inclusion of strong security measures such as encryption protocols and detailed audit logs not only safeguarded sensitive personal and health information but also built trust among all stakeholders. Importantly, no data breaches were recorded throughout the testing phase or live operation, reinforcing the system's credibility and reliability in handling sensitive medical data.

5. Summary

This model, a novel mobile based application for blood donation in emergency situation was built on a secured and scalable architecture. It integrates GPS-enabled donor location services, real-time hospital inventory monitoring, and automated SMS/email notifications to enhance both efficiency and donor engagement. Evaluation results showed a remarkable reduction in donor-recipient matching time from several hours to within 20 minutes alongside a 34% increase in repeat donations. The model will improve the management of blood in blood banks, reducing shortages and wastage with a better user-friendly interface and strong security features. It was executed using C# and ASP.Net for the front end, with SQL Server as the database engine. The system was equipped with modules for donor registration, blood request handling, inventory tracking, and admin control panels for hospitals. Multiple levels of testing including unit, integration, and user acceptance testing confirmed the system's performance, reliability, and usability.
The mobile-based blood donation management system has proven to be an effective, user-centered solution that connects donors, hospitals, and patients more quickly and securely. By combining real-time tracking, automated communication, and robust data protection, it not only streamlines emergency response but also builds long-term trust and engagement among donors. The system's success in improving efficiency, reliability, and participation highlights its transformative potential in strengthening emergency healthcare delivery. With further expansion and integration into broader health networks, this application can make blood donation more responsive, accessible, and impactful, ultimately saving more lives when every second counts.

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