IJVAST | Vol. 1, Issue 2 | Feb 2026 | Open Access — Peer Reviewed Research Paper

Smart Blood & Organ Donation Management System

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Abstract—Timely access to compatible blood units and viable donor organs remains one of the most persistent bottlenecks in emergency and transplant care, particularly when manual coordination between hospitals, blood banks, and registered donors introduces delay at the exact moment delay is least affordable. This paper presents the design, implementation, and evaluation of a Smart Blood & Organ Donation Management System that unifies donor registration, real-time blood inventory tracking, geolocation-based donor discovery, and organ-recipient compatibility prediction within a single coordinated platform. The system integrates four components — a donor-recipient matching engine that ranks eligible donors by blood-group compatibility, geographic proximity, and donation eligibility windows; a blood inventory management module that maintains live unit counts across participating blood banks segmented by group and component; an organ compatibility prediction module that estimates cross-match viability from blood group, HLA-typing, and organ-specific clinical parameters; and an emergency alert and notification module that broadcasts verified requests to eligible donors and partner facilities within a configurable radius. A dataset of 25,400 donor records, 8,200 blood-bank inventory entries, and 3,100 organ-recipient waitlist cases, collected from partner hospital records and public donor registries, was used to develop and evaluate the matching and prediction components. The matching engine achieved a compatibility match accuracy of 96.3% against clinical cross-match outcomes, and the organ compatibility predictor achieved an AUC of 0.89 on held-out waitlist cases. An eight-week pilot across twelve partner hospitals and blood banks processed 512 emergency requests, reducing the average donor response time from 47 minutes to 14 minutes and raising the emergency request fulfilment rate from 68.4% to 92.4% relative to the prior manual coordination process. The paper documents the system architecture, module design, evaluation methodology, observed limitations relating to rural connectivity and registry coverage, and the future scope of the work.

Index Terms—Blood Donation, Organ Donation, Healthcare Informatics, Donor-Recipient Matching, Blood Bank Management, Machine Learning, Geolocation, Emergency Alert System, HLA Compatibility, Decision Support System, Transplant Coordination.

I. INTRODUCTION

Emergency blood requirements and organ transplant matching share a common structural problem: a compatible supply may exist somewhere in a city or region at the moment it is needed, but locating it, verifying its eligibility, and coordinating its transfer through phone calls and manual registers consumes time that critically ill patients frequently do not have [1], [2].

This burden is particularly acute outside major metropolitan hospitals, where blood banks operate with limited staff and organ waitlists are coordinated through fragmented, paper-based or spreadsheet-based records. A request for a rare blood group or a matching organ often depends on informal networks of contacts rather than a searchable, verified registry, and the resulting delay directly affects patient outcomes [3].

Two complementary strands of prior work are relevant here: blood bank inventory systems, which digitise stock records but rarely rank or route requests to the nearest eligible donor, and organ allocation systems, which formalise waitlist priority but are typically confined to a single transplant network rather than integrated with live donor availability [4].

II. RELATED WORK

A. Blood Bank Management Systems

Early blood bank software digitised stock ledgers and donor contact lists, improving record-keeping but leaving the task of identifying an eligible donor for a specific request to manual phone-based outreach, which scales poorly during surges in demand [5].

B. Organ Allocation Systems

Formal organ allocation frameworks rank waitlisted recipients by clinical urgency and compatibility, and have been shown to improve equity of access, but are generally designed around a single transplant network's waitlist rather than a live, cross-facility donor and organ availability picture [6], [7].

C. Geolocation-Based Emergency Response

Location-aware dispatch systems in adjacent domains, such as emergency medical services and blood-delivery logistics, demonstrate that ranking responders by proximity and current availability meaningfully reduces response time, motivating a similar approach for donor discovery [8].

D. Machine Learning in Healthcare Matching

This paper proposes a Smart Blood & Organ Donation Management System that combines a geolocation-aware donor-recipient matching engine with live inventory tracking and an organ compatibility predictor, producing ranked, actionable donor and organ matches within seconds of a verified request being raised.

The principal contributions of this work are: (1) a donor-recipient matching engine combining blood-group compatibility, proximity, and eligibility filtering; (2) a real-time blood inventory management module spanning multiple partner blood banks; (3) an organ compatibility prediction module estimating cross-match viability from clinical parameters; (4) an emergency alert and notification module for time-critical broadcast; and (5) an empirical evaluation covering matching accuracy, prediction quality, and an eight-week multi-hospital pilot.

Machine learning approaches to clinical compatibility prediction, including HLA-typing based transplant matching models, have shown that learned cross-match estimators can approximate laboratory compatibility screening with useful accuracy ahead of full clinical testing, supporting their use as a triage and prioritisation aid rather than a replacement for clinical verification [9], [10].

Fig. 1 — Layered System Architecture of the Proposed Smart Blood & Organ Donation Management System

Layer	Principal Components and Responsibilities
Presentation Layer	Request dashboard, live inventory view, donor mobile interface
Coordination Layer	Emergency alert & notification module, radius escalation logic
Matching Layer	Donor-recipient matching engine, organ compatibility prediction
Data Layer	Donor registry, blood-bank inventory, organ-recipient waitlist

TABLE I — Comparative Analysis: Manual Coordination vs. Single-Facility Software vs. Proposed System

Feature	Manual Coordination	Single-Facility Software	Proposed SBODMS	Benefit to User
Donor Discovery	Manual phone outreach	Static contact directory	Proximity-ranked live matching	Faster eligible-donor contact
Inventory Visibility	Per-facility register	Single blood bank only	Cross-facility live inventory	Fewer unnecessary transfers
Organ Compatibility	Lab cross-match only	Not available	Pre-screened predictive shortlist	Faster clinical triage
Emergency Broadcast	Ad hoc calling	Not available	Radius-based auto-escalation	Reduced response time
Eligibility Tracking	Manual record checks	Basic donor profile	Automated eligibility filtering	Fewer ineligible contacts
Scale of Coordination	Single facility	Single blood bank	Multi-hospital network	Broader effective supply

TABLE II — Matching Accuracy, Prediction Quality, and Pilot Study Results

#	Model / Metric	Result	Comparison	Observation
1	Nearest-facility-only baseline	81.2%	Baseline	Weak for rare groups
2	Blood-group-filter-only baseline	85.7%	Baseline	No proximity ranking

#	Model / Metric	Result	Comparison	Observation
3	Full matching engine (selected)	96.3%	Both baselines	Best match accuracy
4	Organ compatibility predictor	AUC 0.89	Held-out waitlist	Strongest for kidney, cornea
5	Pilot — donor response time	47 → 14 min	-70%	Across 8-week pilot
6	Pilot — request fulfilment rate	68.4% → 92.4%	+24.0 pts	12 partner facilities

III. SYSTEM ARCHITECTURE

A. Architectural Overview

The proposed system follows a four-layer architecture consisting of a data layer, a matching layer, a coordination layer, and a presentation layer, as summarised in Fig. 1. Layer separation allows the matching engine and compatibility predictor to be retrained or extended independently of the inventory database and the hospital-facing interface.

B. Data Layer

The data layer maintains a verified donor registry with blood group, location, and eligibility status, a multi-facility blood inventory table segmented by group and component, and an organ-recipient waitlist recording clinical parameters used for compatibility scoring.

C. Donor-Recipient Matching Engine

The matching engine filters registered donors by blood-group compatibility and donation eligibility window, ranks the remaining candidates by geographic proximity using haversine distance over last-known location, and applies a recency-weighted availability score so donors who have confirmed recent availability are ranked above those who have not responded to recent requests.

D. Blood Inventory Management Module

The inventory module maintains live unit counts per blood group and component across all participating blood banks, flags units approaching expiry, and automatically routes a request to the nearest facility holding sufficient stock before escalating to a donor broadcast.

E. Organ Compatibility Prediction Module

The compatibility module estimates cross-match viability from blood group, HLA-typing markers, organ type, and recipient clinical parameters using a gradient-boosted classifier trained on historical waitlist outcomes, producing a ranked shortlist for clinical review rather than an automated allocation decision.

F. Emergency Alert & Notification Module

When a verified request cannot be satisfied from existing inventory, this module broadcasts a request to eligible donors and partner facilities within a configurable radius via SMS and push notification, and escalates the radius automatically if no response is received within a set interval.

G. Presentation Layer

The presentation layer provides hospital staff with a request dashboard, blood banks with a live inventory view, and donors with a mobile interface for registration, eligibility status, and response to nearby requests.

IV. METHODOLOGY

A. Dataset Preparation

A dataset of 25,400 donor records, 8,200 blood-bank inventory entries, and 3,100 organ-recipient waitlist cases was assembled from partner hospital records and public donor registries, with clinical fields anonymised prior to use.

B. Experimental Protocol

The waitlist dataset was partitioned into training, validation, and test subsets in a 70:15:15 ratio using a stratified split by organ type, so that compatibility prediction performance could be assessed separately for each organ category. Matching-engine parameters were tuned on the validation subset.

D. Evaluation Metrics

Matching quality was measured as compatibility match accuracy against recorded clinical cross-match outcomes. Compatibility prediction quality was measured using area under the ROC curve (AUC) on held-out waitlist cases. Operational impact was measured as average donor response time and emergency request fulfilment rate.

E. Implementation Environment

The prototype was implemented in Python 3.11 using scikit-learn and XGBoost for the prediction models, PostgreSQL with PostGIS for geolocation queries, and Django for the application layer. The interface was built with HTML5, CSS3, and Chart.js,

C. Baseline Models

Three approaches were compared for donor ranking: a nearest-facility-only baseline, a blood-group-filter-only baseline with no proximity ranking, and the full matching engine used in the final system. All approaches were evaluated against the same set of historical emergency requests.

and all experiments were executed on a machine with an Intel Core i5 processor and 8 GB of memory.

F. Pilot Study Design

An eight-week pilot was conducted across twelve partner hospitals and blood banks. Emergency request handling was recorded for the first two weeks under the prior manual coordination process, and compared against the following six weeks using the full system.

V. RESULTS AND DISCUSSION

A. Matching and Prediction Accuracy

As reported in Table II, the donor-recipient matching engine achieved a compatibility match accuracy of 96.3% against recorded clinical cross-match outcomes, exceeding the nearest-facility-only baseline at 81.2% and the blood-group-filter-only baseline at 85.7%. The organ compatibility predictor achieved an AUC of 0.89 on held-out waitlist cases, with the strongest performance observed for kidney and cornea cases, where historical waitlist volume was largest.

The improvement over the baselines was most pronounced for time-critical requests, where proximity-aware ranking reduced the number of donors contacted before a successful match was found.

B. Operational Impact

Across the eight-week pilot, average donor response time fell from 47 minutes under manual coordination to 14 minutes with the full system, and the emergency request fulfilment rate rose from 68.4% to 92.4% over the same comparison, as summarised in Table II.

C. Pilot Study Outcomes

Partner hospital staff identified the live inventory dashboard and the automatic radius-escalation feature of the alert module as the two most valued components, noting that both reduced the number of manual phone calls required per request.

D. Discussion

The results indicate that combining proximity-aware donor ranking with live cross-facility inventory visibility addresses a coordination gap that neither isolated blood-bank software nor manual outreach resolves well. The pilot cohort of twelve facilities is modest, so the reported fulfilment-rate and response-time figures should be treated as indicative rather than conclusive across all care settings.

VI. LIMITATIONS

Several limitations qualify these findings. First, donor location accuracy depends on devices reporting recent GPS data, and coverage is weaker in low-connectivity rural areas. Second, the compatibility predictor is trained primarily on kidney and cornea cases, and its accuracy is less established for rarer organ categories with limited historical volume. Third, the eight-week pilot involved twelve facilities and cannot support strong claims about performance at national registry scale. Finally, the system prioritises candidates for clinical review and does not replace laboratory cross-matching prior to any transfusion or transplant procedure.

VII. FUTURE SCOPE

Future development will proceed along four directions: expanding organ-specific training data to strengthen prediction quality for less-represented organ categories; integrating with national donor registries to widen coverage beyond partner facilities; adding offline-capable mobile clients for low-connectivity regions; and conducting a longer, multi-region pilot to validate response-time and fulfilment-rate improvements at larger scale.

VIII. CONCLUSION

This paper presented a Smart Blood & Organ Donation Management System that integrates donor-recipient matching, live blood inventory tracking, organ compatibility prediction, and emergency alerting within a single platform. The matching engine achieved a compatibility match accuracy of 96.3%, and the organ compatibility predictor achieved an AUC of 0.89 on held-out waitlist cases.

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An eight-week pilot across twelve partner facilities reduced average donor response time from 47 to 14 minutes and raised emergency request fulfilment from 68.4% to 92.4%, indicating that coordinated, proximity-aware matching can meaningfully ease the operational burden of time-critical blood and organ requests. The limitations relating to rural connectivity, organ-category coverage, and pilot scale define a clear agenda for the extensions outlined above.

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