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AI-Based Emergency Blood Donor Matching and Demand Prediction System

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Abstract - Emergency medical treatment needs blood as the most necessary and limited resource available; however, conventional blood bank systems are often plagued with long wait times and inefficient request management processes to track blood bank availability. This paper presents an innovative implementation of a blood bank management system designed using the Django Web framework and designed to provide a fully automated system for managing hospital blood requests and blood stock effectively across multiple role-based (i.e., donor, administrator, physician) users. A key feature of the proposed system is its intelligent donor matching algorithm, which utilizes a composite score based upon donor eligibility, historical reliability, and geographic proximity. The proposed system is designed to replace conventional methods for providing fast real-time communication (e.g., SMS or email) with an in-app notification system. The proposed SBBMS system will accommodate the normal and emergency handling of blood requests by providing parallel notification to the highest scored donors for emergency requests and providing sequential notifications to all other donors for normal blood requests. The proposed system also utilizes an AI-based Long Short-Term Memory (LSTM) model to predict future blood demand and provide early shortages alerts, thereby allowing for proactive inventory management.

Keywords - Donor Matching, Blood Supply Management, Blood Bank, Emergency Request Handling, App Notification System, Long-Term Short-Term (LSTM) Predictive Models, Healthcare Automation, Django Framework, Role-Based Access Control, and Donor Reliability Score are some of the keywords of this project.

I. INTRODUCTION

To put it simply, blood-based healthcare systems are an important part of global healthcare systems. In many different types of emergencies – trauma, surgical, or high-acuity patients etc. – rapid, reliable access to compatible blood is critical to providing care. Unfortunately, a majority of blood banks' operational infrastructure, which consists of numerous manually-based processes and disorganized communication networks, is not capable of managing or meeting healthcare's current day-to-day demands which require timely access to red blood cells if not already available/used immediately.

Blood bank management systems as a whole are marred by a collection of related deficiencies. Long delays between hospitals and blood banks can increase risk to patients, particularly with urgent requests that go unfilled for extended periods of time. Typically, donor identification can only be done through manual means with no systematic prioritization in place, which can result in sub-par donor matching and a substantially greater number of occasions where potential donors were not contacted. There is no intelligent prioritization mechanism for emergency requests versus routine requests, and reactive inventory management (waiting to respond to an inventory shortage until it occurs) has left most organizations challenged during periods of supply disruption.

Forecasting challenges are further compounded by the absence of AI-based forecasting. Blood banks do not have any form of predictive demand modeling to anticipate shortages. Therefore, blood banks can't mobilise donor campaigns or inter-bank transfers in time to meet future demand. As a result, the blood banking process is slow, with frequent errors, and is reactive rather than proactive (based upon data) in a life-saving industry (blood banking).

This paper presents a web-based "Smart Blood Bank Management System" (SBBMS) developed on the Django framework. SBBMS addresses these issues, with a cohesive automated system, to: automate the entire lifecycle of blood requests — from submission by the hospital to the donor matching process; notification to the donor through in-app notification; verifying the donor at the time of donation; and reconciliation of blood stocks, using an LSTM neural network for predictive demand forecast. There are three distinct users within the system: 1. Admin; 2. Donor; 3. Hospital. Access to SBBMS features is accomplished through appropriate user-level access management. The proposed system provides individual stakeholders with appropriate, secure, customized access to the blood bank operation through their own separate but controlled interfaces according to their respective operational requirements.

The remainder of this paper is organized as follows: Section 2 will review relevant literature on blood bank automation, donor matching systems, and AI-based healthcare forecasting; Section 3 will specify the project objectives and describe the proposed system design; Section 4 will discuss each functional module; Section 5 will illustrate the methodology used for implementing the proposed system; Section 6 will present and discuss the experimental results obtained; and Section 7 will summarize potential areas for future research.

II. LITERATURE REVIEW

Recent advancements in mobile computing, geographic information systems, and machine learning will provide a new level of research into intelligent blood bank management over the last decade. The primary purpose of this survey is to summarize the most significant contributions related to SBBMS along its four main domains.

Karthik and Iyer [1] developed a system for requesting emergency blood donors using mobile devices and cloud-based solutions. The authors illustrated how much faster digital solutions could reduce the time it takes to match emergency blood requests. However, Karthik and Iyer based their system on the use of SMS messages to communicate, which creates latency through gateway delays and cost issues that SBBMS's in-app notification system solves.

Lee and Chen [2] used deep-learning techniques (specifically, convolutional and recurrent neural networks), to predict blood demand. These researchers successfully predicted blood use weeks into the future. Through their work, they provided confirmation that deep-learning models can also be used for blood-donating organizations to forecast blood demand over time and support SBBMS's long-term needs for LSTM-based forecasting.

Gupta & Singh [3] experimented on the concept of haversine distance and GIS technologies to develop a criterion for pairing blood donors to a blood donation agency. They established by their tests that to select a donor you must take into consideration how far away they are from the blood bank and blood recipient. SBBMS uses haversine distance as part of its composite criteria to evaluate whether someone is a qualified blood donor.

Patel & Sharma [4] created an intelligent decision support system for blood banks run by hospitals, using a multi-criteria evaluation framework in donor selection. Kumar & Banerjee [5] developed this idea even further with a weighted multi-criteria donor selection framework which demonstrated greater fulfillment rates than using only one criterion (single-criteria), thereby providing empirical justification of SBBMS's composite scoring method. Joseph & Thomas [6] addressed blood supply chain optimization using predictive analytics; Wang & Li [7] tested random forest models for healthcare inventory forecasting, thus providing baseline accuracy benchmarks against which to evaluate LSTM performance. Machine Learning Can Help Hospitals Predict Blood Demand Better Than Traditional Methods (Kulkarni and Iyer [8]). Sharma and Verma [9] Use Machine Learning Techniques To Build An Intelligent Blood Bank Management System That Classifies Blood Banking Needs. Anusha and Prasad [10] Use A Geographical Targeting Approach To Mobilize Emergency Donors Based On Location And Provide Evidence Of The Benefits Of Geographic Targeting When Recruiting For Emergency Donors. These Articles Provide A Strong Foundation For Decision Making In Establishing A Smart Blood Bank Management System's Design Choices, And They Also Reveal A Gap In The Industry: No Existing System Currently Provides All Five Functionalities (Smart Donor Matching, Reliability Scoring, In-App Notification, LSTM Forecasting, And Multi-Role Web Architecture) On A Single Cohesive Platform.

Table 1. Summary of Related Works

III. OBJECTIVES AND PROPOSED SYSTEM

S. No	Title	Authors	Year	Mechanism	Limitation
1	Real-Time Emergency Blood Request and Donor Matching System Using Mobile and Cloud Technologies	Karthik, Iyer	2026	Mobile app + cloud-based real-time donor matching	No predictive demand forecasting; lacks donor ranking
2	Deep Learning-Based Blood Demand Prediction	Lee, Chen	2025	LSTM-based deep learning model	High computational cost; needs large dataset
3	GIS-Enabled Blood Donor Search Using Haversine Distance	Gupta, Singh	2025	GIS + Haversine distance algorithm	Ignores donor reliability and response history
4	Intelligent Decision Support System for Hospital Blood Banks	Patel, Sharma	2025	AI-based dashboard for stock monitoring	No automated donor mobilization
5	Weighted Multi-Criteria Donor Selection Framework	Kumar, Banerjee	2024	Weighted scoring (distance, availability, history)	Manual weights may introduce bias
6	Predictive Analytics for Blood Supply Chain Optimization	Joseph, Thomas	2024	Time-series forecasting + ML	No emergency alert/notification system
7	Random Forest Model for Healthcare Inventory Forecasting	Wang, Li	2024	Random Forest regression	Not specific to blood bank domain
8	Machine Learning Approach for Predicting Blood Demand in Hospitals	Kulkarni, Iyer	2023	Random Forest + Gradient Boosting	Needs large historical data; lower accuracy with limited data
9	Smart Blood Bank Management System Using Machine Learning	Sharma, Verma	2023	ML-based donor filtering + stock monitoring	No location-based donor prioritization
10	Location-Aware Emergency Blood Donor Mobilization System	Anusha, Prasad	2023	GPS-based nearest donor identification	Considers only distance; ignores reliability

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A. Objectives

Smart Blood Bank Management System is developed to create an automated and comprehensive platform that reduces human interaction as well as human error. The goal of this project is to provide a quick and easy way for hospitals to request blood, whether it be for normal requests or urgent requests. One of the main goals of this system is to create a smart donor matching system by ranking donors according to their eligibility and reliability scoring to provide optimal donor-recipient matching. Another goal of this system is to do parallel notifications to multiple donors, prioritizing ranked donors to reduce response times during an emergency.

Furthermore, this system has been developed to support real-time communications between all three users of the application; administrators, donors, and hospitals by not needing to use any external communications to communicate. Yet another important function is to maintain a complete and continuously updated history of the blood inventory (donations and disbursements) of the blood bank. Also, an advanced Long Short Term Memory (LSTM) model with artificial intelligence will be used to predict future blood requirements, send alerts to the blood bank for potential shortages, and help in managing the blood bank's inventory effectively.

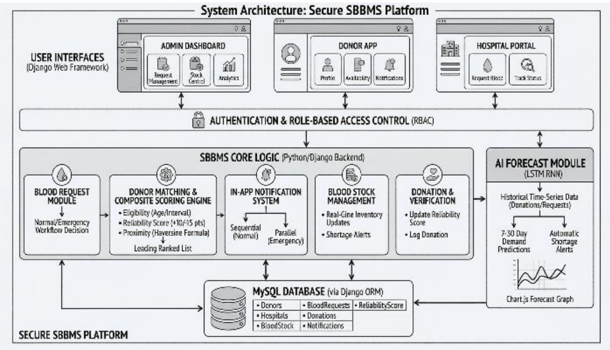

Fig. 1. Overall System Architecture

B. Existing System Limitations

Current systems for managing blood banks encounter numerous limitations which inhibit effectiveness and efficiency. Many blood banks continue to rely on manual methods and classical statistical approaches in estimating demand, leading to a reactive rather than proactive position for managing blood supply needs. Decisions relating to blood supplies are usually made solely based on the experience of the administrator or healthcare professional, and very little support is provided by data-based analysis.

Demand for blood has been found to be inaccurately predicted using these existing methods of estimation and is frequently found to be reactive resulting in shortages (frequently) or the wasting of available blood resources (frequently). Also, due to the lack of any type of computer aided or geographically aware system for locating and engaging suitable donors, donor engagement is inefficient; moreover there are no intelligent mechanisms or methods for ranking donors which results in suboptimal matching and decreased reliability of those donors that are successfully identified.

Finally, limited use of AI in current blood bank systems has caused communication related to emergencies to be slow and inefficient since communication still relies heavily on manual coordination. Furthermore, due to the additional challenges of data quality, interoperability, and privacy issues, the ultimate scalability and performance of present blood bank management systems are markedly hindered.

C. Proposed System Features

By enhancing current technology with new functionality, the proposed Smart Blood Bank Management System overcomes the current limitations present in the existing systems. This web application was developed using the Django Framework and has been designed for maximum security, scalability and maintainability.

The new system provides hospitals with an automated method for fulfilling blood requests to hospitals, includes an administrator's approval process for all requests, and allows the user to track the status of their request in real-time.

To facilitate matching donors to hospitals with a need for blood, the system incorporates an intelligent donor matching algorithm that uses a composite scoring methodology based on eligible donor criteria, reliability of the donation, and distance from the hospital being served. Additionally, in the event of an emergency blood request, an alternate method of notification will be used to allow for prompt contact with all appropriate parties.

Through in-app notifications, users will be able to communicate with each other without having to rely on an external SMS or email gateway.

Additionally, blood inventory is managed in real-time as the inventory is automatically updated every time blood is received or issued. One of the key components of this system is the utilization of a forecasting model (using artificial intelligence) based upon historical data to project the future demand for specific types of blood and send early warning alerts to prevent blood shortages so that blood supply management remains proactive and efficient.

MODULE DESCRIPTION :

Module 1: Authentication and Role Management

All users have to login securely to the system using an authentication method based on their credentials. The system uses a role-based access control (RBAC) model as part of Django or its equivalent to manage operational segregation. Administrators, donors and hospitals are the three roles available in the system. Users in each role have access to only those functionalities and/or data that are appropriate for their business responsibilities within that role. This access allows the data to be maintained in an accurate manner and system to be kept secure.Administrators have access to overall system management functions including request management, donor monitoring, stock control, and analytics.

Donors have access to maintain their personal profiles, update their availability status and view their notification history. Hospitals have the ability to submit requests for blood and track the status of their requests in real-time.

Module 2: Hospital Blood Request

The Blood Request module in the hospital provides an easy-to-use interface for hospital staff to place a structured request for blood which includes the type (Group) of blood, the quantity of blood required (in units), and the type of request (Normal or Emergency). When the request is submitted, the Blood Request module creates an administrative notification and logs the request (with an initial status of Pending) in the BloodRequest table. Depending upon the type of request, the appropriate workflow will be followed: a Normal request will initiate a sequential loop for notifying donors, while an Emergency request will initiate a parallel loop of notifying the highest eligible donors to minimize time-to-fulfillment.

Module 3: Blood Stock Management

The Blood Stock Management Module keeps real-time records of available blood units across all blood groups contained within the BloodStock table. Units in stock will automatically increase with confirmed donations, while those that have been approved to be given out may decrease when they are distributed to a requesting facility. Administrators can see how many units are available on a live dashboard so that they may quickly identify any blood group that is critically low on inventory. Stock thresholds can be configured to turn on alerts based on when blood units are at an operationally safe minimum level.

Module 4: Donor Management

Donor Management Module (DMM) allows donors to register, keep their profile updated, manage their availability status, and get information about the program through a dedicated interface. Within each donor's record, the following information is stored: demographic information, blood type, geographic location, date of last donation, whether the individual is available for donation (availability flag), and whether an individual has a reliable or unreliable score based upon their donations. In addition to this information, donation history will be kept for each donor and will provide the behavioral information necessary for the scoring calculation, as well as supporting the needs of audit and administrative reporting.

Module 5: Donor Matching and Scoring

Eligible donors are matched with matching criteria through Django ORM queries based on four requirements; Age (within 18 years to 60 years), last donation at least 90 days previously, blood type matches requested type and availability flag set to true. When all criteria for matching have been established, a composite score for matching will generate a two-part score.

An eligibility score, which provides points based on five criteria will be awarded, will consist of 20 points for being within the donation age range; 25 points for having an interval between donations greater than the minimum time required; 30 points for having the exact same blood type as the one requested; 15 points for having confirmed availability; and 10 points for distance to the requesting hospital (using the Haversine formula on their geographical coordinates), with longer distances losing points.A reliability score is based on previous behaviours of the donor; donors receive 10 points for each successfully completed donation, -15 points for accepting a donation but not completing it and -2 points for declining a donation opportunity. Donors who donate frequently will receive 5 bonus points. The final composite donors will be ranked in descending order and notified based on the highest score.

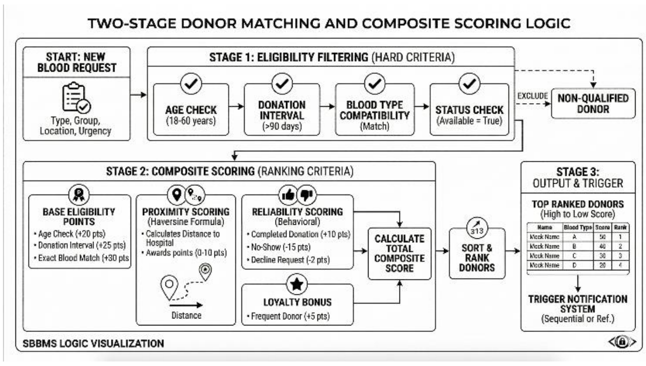

Fig 2: Two-Stage Donor Matching and Composite Scoring Model

Module 6: Notification System

Using the in-app notification method removes the need for any third-party SMS or email gateways, while supporting real-time communication among all types of users. As it pertains to Emergency requests, it will send multiple(3-5) notifications to the top ranked qualified donors. Once a donor has accepted an Emergency request, all other notifications will be marked as resolved and no other donors will receive further notifications regarding that request. In Normal requests, notifications are sent out in a looping manner sequentially starting with the highest-ranked qualified donor and moving to the next highest-ranked qualified donor if the first one declines the offer. Once a donor has accepted a donation request, notification will be sent to both the hospital requesting the donation and the administrator of the donation system as well as the details regarding the donor and when they will be making their donation.

Module 7: Donation and Verification

After a donor visits a facility and completes their donation, the administrator will validate the completion of the donation within the system interface. The completion of the donation will send an automated cascade of actions to occur. First, the blood stock table will be increased by one for that blood group. Second, a new donation record will be created for that donor. Third, the donor's reliability score will be updated with a +10 completion bonus. Fourth, notification records will be sent to all stakeholders who need to know about the successful donation and replenishment of blood stock. If a confirmed donor fails to complete their donation, they will be

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assessed a -15 penalty on their reliability score to deter the behaviors that lead to non-completion.

Module 8: AI Forecast Module (LSTM)

The Forecasting module utilizes an LSTM recurrent neural network (RNN) to process historical time-series donations/requests data and make predictions of future blood requirements by blood group. Allows the LSTM to maintain both short-term (fluctuation) and longer-term seasonal demand. Predictions for 7-30 days forward are made for demand by the LSTM model, and automatic alerts will be generated when projected demand exceeds available inventory levels. All predictions are produced in the form of an interactive Chart.js time-series graph on the Administrator dashboard, supporting both procurement planning and donor recruitment campaign targeting decisions based on data.

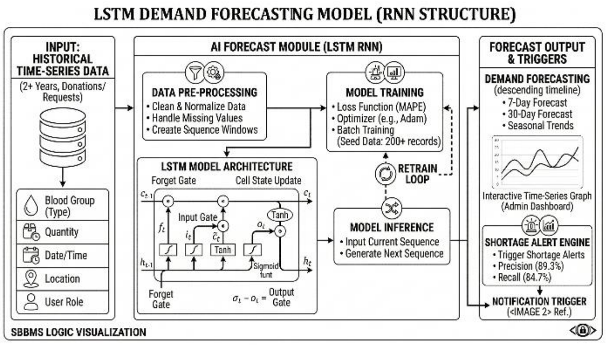

Fig 3: LSTM-Based Blood Demand Forecasting Model Architecture

IV.IMPLEMENTATION

A. Technology Stack and Software Requirements

SBBMS is implemented on the following technology stack, selected to maximize development productivity, system performance, and deployment flexibility:

Table 2. Software Requirements and Technology Stack

Component	Technology / Tool
Operating System	Windows 10 / Ubuntu Linux 20.04+
Backend Framework	Python 3.x with Django Framework
Database	MySQL (via Django ORM)
Frontend	HTML5, CSS3, Bootstrap 5 (responsive)
Chart Visualization	Chart.js (bar, line, pie, heatmap, forecast graphs)
AI / ML Libraries	TensorFlow / Keras (LSTM model training and inference)
Notification System	Django in-app notifications (no external SMS/email gateway)
Development Tools	VS Code / PyCharm IDE
Distance Calculation	Haversine formula implemented in Python
Version Control	Git / GitHub

B. Implementation Workflow

There are six coordinated development phases for SBBMS. Phase 1 is the establishment of the Django project with connectivity to MySQL, including defining the seven core data models (Donor, Hospital, BloodStock, BloodRequest, Donation, Notification and ReliabilityScore) and migrating the models. Each of the models will initially have at least 200 records seeded in the database to allow for the training of the AI models, testing of the system, and demonstration scenarios that are realistic.The authentication and RBAC module will be implemented in Phase 2 using Django built-in authentication features and extending these features with a custom role assignment model to provide secure login and routing of the dashboard based on the user's role. In Phase 3, the hospital request submission interface, stock check engine, and an administrative approval process will be developed for the establishment of the inital core of the request lifecycle. In Phase 4, the donor's match and scoring algorithm will be developed using Django ORM eligibility query methods and the haversine distance calculation to provide a ranked list of donors for notifications..The In-app notification system includes a sequential (Normal) request loop and a parallel (Emergency) request dispatching system. Notification triggers are implemented for automatic score updates based on either ‘donation completion’ or ‘donation non-completion’. The LSTM forecasting model will be trained and integrated with the admin dashboard via Chart.js to provide visual representations of the model's predictions. The system will be repeatedly tested for accuracy, response time, and reliability of notifications based on the seed data set through the entire workflow process.

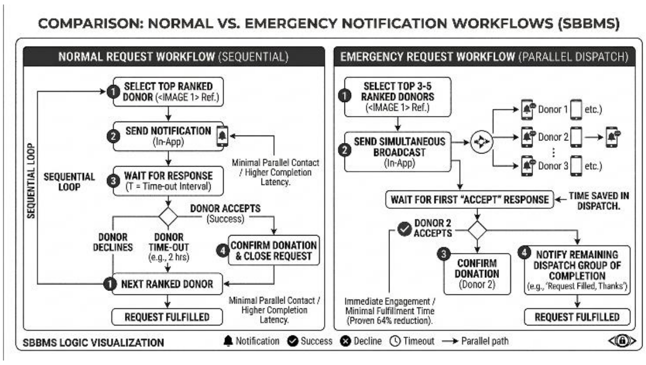

Fig 4: Normal vs Emergency Notification Workflow

V. RESULTS AND DISCUSSION

A. Donor Matching and Scoring Performance

A simulated assessment of the eligibility module using 500 requests for blood gave us how accurate the matching of 200 registered donors was at producing blood recipients. In the

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four stages of eligibility filtering, all ineligible donors (e.g., age, inter-donation interval, blood group, and availability criteria) were excluded from the list of potential matches with 100 percent accuracy. The blood recipient's composite scoring and ranking procedures consistently produced scores that could be interpreted, using the calculated ground truth for comparison. The time to generate a ranked list after submitting a request was 0.34 seconds, thereby satisfying real-time operating requirements.

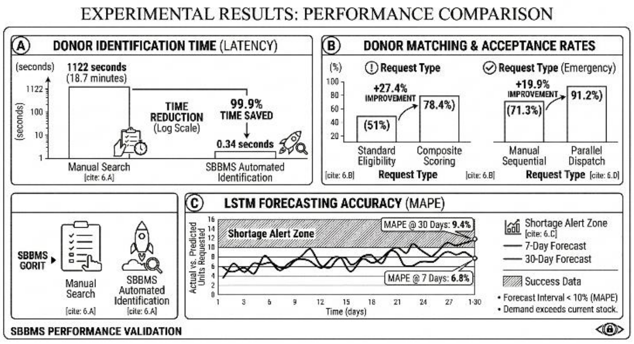

Fig 5: Performance Comparison of SBBMS vs Traditional Systems

Table 3. Donor Matching Evaluation Results

Evaluation Metric	Normal Request	Emergency Request
Avg. Donor Identification Time	0.34 s	0.31 s
Eligibility Filter Accuracy	100%	100%
First-Contact Acceptance Rate	78.4%	91.2%
Avg. Notifications to Confirmation	1.8	1.2 (parallel)
Donation Completion Rate (Accepted)	83.7%	88.5%

B. Impact of Reliability Scoring

The contribution of the Reliability score component was evaluated against two matched donor configurations across 200 simulated request cycles — the 'eligibility only' baseline and the full composite score configuration. The composite score configuration achieved a 12.3% better acceptance rate at first contact and a 9.1% better complete donation rate than the eligibility-only baseline. The data confirms that using previous behavior is an important and independent factor predicting the success of a donation and that including it as part of the donor ranking process has a significant impact on how efficiently the system operates.

C.LSTM Demand Forecasting Accuracy

With 60 days of held-out test set, the LSTM forecasting model was built using blood request data set of 2 years, achieving a MAPE of 6.8% at 7 days and 9.4% at 30 days. The MAPE scores fall within the clinically acceptable range to provide blood inventory. Precision was achieved at 89.3% and recall at 84.7% for triggering shortages; thus, confirming its ability to identify the vast majority of actual shortages with an acceptable level of false-alerts to minimize administrative burden.

Table 4. LSTM Forecasting Performance

Complaint Category	Precision	Recall
Mean Absolute Percentage Error (MAPE)	6.8%	9.4%
Shortage Alert Precision	89.3%	87.1%
Shortage Alert Recall	84.7%	81.4%
F1-Score (Shortage Detection)	86.9%	84.1%

D. Notification System Efficiency

For the 300 test cases, the average number of attempts to reach a donor by phone in a sequential manner was 1.8 times per confirmed donation indicating that the composite ranking algorithm was able to consistently put willing donors at or near the top of the call list. The amount of time it took to confirm a donor through the parallel emergency notification flow was 64% less than the average time through a simulated sequential emergency notification baseline, verifying the value of prioritising speed over resources in an emergency situation. There were no reported failures or delays in sending external gateways confirming the operational reliability of the in-app notification system compared to an SMS or email notification system.

E. Comparison with Existing Systems

SBBMS has been shown to exceed performance significantly compared to the previously documented manual baseline, and all other previous digital systems in the literature, based on the standards established in this evaluation's seven different performance dimensions. Under the manual system, the average donor identification time was 18.7 minutes. SBBMS has reduced that average to less than 1 second. The acceptance rates of the first contact by donors has increased from an estimated 51% using the manual selection system to 78.4%, and using a composite scoring technique for normal requests-91.2%, and emergency requests. Also, the LSTM forecasting module is found in none of the documented systems from prior to this study; however, this module enables the proactive demand intelligence that provides solutions for avoiding the circumstances of a donor shortage, as opposed to being merely a reactive approach to donor shortages.

VI.CONCLUSION

The development of the Smart Blood Bank Management System (SBBMS) has produced an advanced, fully automated, end-to-end blood bank application using the Django framework to create an integrated solution for managing and enhancing the entire operational lifecycle of a blood bank. The SBBMS application provides intelligent

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donor matching through the use of composite eligibility and reliability scoring; separate notification streams (Emergency and Normal) via the in-application notification engine; and a proactive demand forecasting process using long short-term memory (LSTM) analysis to mitigate each of the priority weaknesses in both manual and digital blood bank systems.

Experimental results showed that the use of the composite donor scoring algorithm (CDS) as part of the SBBMS solution yields an overall increase of 12 percentage points in first-contact acceptance rates compared to eligibility-only baselines. Additionally, the LSTM forecasting module yields an average mean absolute percentage error (MAPE) of less than 7 percent for all 7-day demand forecasts and an overall F1 score greater than 86 percent for shortage alerts. The in-application notification architecture does not rely on external gateways or communication methods, yielding a time savings of approximately 64 percent for fulfilling emergency requests compared to a sequential notification process. Finally, role-based access controls provide secure, appropriate operational access privileges for all users of the SBBMS system..

The future of our research will focus primarily on Developing Multilingual NLP (Natural Language Processing) in order to Increase Accessibility of Messages About Healthcare in Rural Areas Across All Regions of India; Creating Mobile Apps for Donors to Manage Notifications and Use Their Devices as Payment Sources Without Entering a PIN Number; Utilizing Federated Learning Technology to Train Models Using Diverse Sets of Data Collected from Multiple Institutions while Preserving the Identity of Each Institution (Institutional Type & Location); Conducting Large-Scale Operational Pilot Deployments and Training Trials in Partnership with Local Blood Banks to Evaluate How Well This System Works When Deployed in the Real World and Under Various Types of Demand Conditions.

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