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IoT Based E-Blood Bank System for Real Time Hospital Monitoring and Inventory Management

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ABSTRACT: The lack of sufficient blood reserves and delayed delivery services in Indian healthcare facilities causes 12,000 daily fatalities. The nation demands 14.6 million units of blood annually yet experiences more than 1 million unit's shortage. Current blood bank management faces difficulties because of inadequate logistic systems and it depends on manual work and lacks unified donor-recipient communication channels. A new web-based e-Blood Bank Management System functions as an innovative tool that creates quick direct connections between blood donors and recipients and blood banks to optimize blood service processes. The system operates through a combined usage of a Node.js and Express.js framework together with React framework and MongoDB database and Vanilla CSS. Users can use the system for blood request submission then receive automatic alerts about donor eligibility and execute location-based searches for nearby blood banks and donation venues. Through its instant connections between donors and recipients and interactive feedback mechanisms this platform cuts delays while enhancing operational results and donating blood encouragement which leads to decreased preventable mortality statistics. The system's flexible structure makes it suitable for national deployment so it can prevent numerous losses of life annually.

KEYWORDS: E-Blood Bank, Blood Donation, Online Blood Bank, Data Management, Instant Connectivity.

I. INTRODUCTION

The lack of available blood supply and delayed delivery procedures in India leads to the daily loss of about 12000 lives [1]. Blood Laboratories fail to meet the national requirement of 14.6 million annual units because manual data practices combine with inadequate distribution systems and poor communication links between blood institutes and blood donors and patients [1], [2]. The absence of operational blood banks in more than 40 districts of the country makes the blood shortage worse across rural communities which are not properly served [1]. The donor-recipient pairing capabilities of Simply Blood have accelerated through their virtual blood donation app although they remain ineffective in critical situations because this platform does not utilize IoT technology and real-time mobile features [3]. This research presents a scalable E-Blood Bank Monitoring System which provides mobile optimization and includes digital capabilities for communication automation and donator notifications and geolocation search for blood camps and hospital inventory monitoring through a unified platform. This system functions with React and Node.js, Express.js and MongoDB technologies to enhance blood logistics operations and support voluntary donations for preventing fatalities across India [1][2][3].

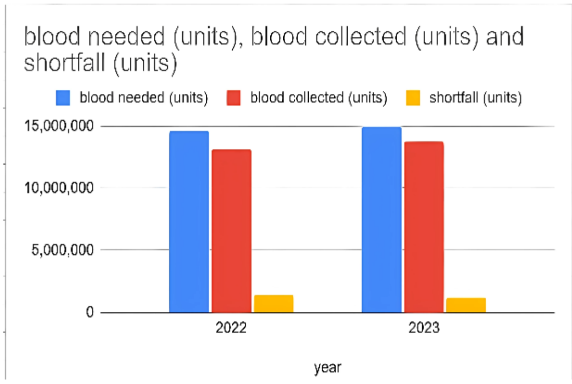

Figure 1: Blood Supply Analysis

See the Figure 1 that illustrates the dire shortage in India's blood supply system where the demand in blood units outstrips actual units by more than 1 million in any year. This analysis shows the urgent need of a real time digital blood management platform that would save preventable deaths.

II. LITERATURE REVIEW

Blood bank management systems have progressed from traditional manual record systems to modern technological platforms during the past years. Web-based systems at their early stage exclusively concentrated on delivering centralized access to donor-recipient information along with data automation features. Researchers Clemen Teena and Sankar created a secure donor-recipient search and login framework according to their paper [4] and Dudani et al. implemented a geospatial database for blood type and regional donor classification. Real-time functionality with mobile capabilities remains absent from these systems even though they improved data storage and retrieval. Both features are mandatory in critical emergency situations.

Emergency and mobile platforms have recently emerged to help decrease blood shortage response times during critical moments. Kaur et al. [5] developed a donor matching application that functioned within a 20-second period to ensure urgent responses to emergencies. Nirajanamurthy built an e-blood bank system with warning protocols that connected donor blood inventory to a national database as well as near-by blood drives search features. The speed benefits of these platforms do not match their capability to integrate IoT technology or develop donor engagement methods based on feedback processes.

Blood bank systems have experienced an enhancement through the integration between Internet of Things (IoT) and data-driven decision support systems. An IoT-enabled model by Shah et al. [6] provides automatic alerts with blood camp location services as well as real-time data synchronization capabilities. Among their research Li et al. [7] examined predictive modeling to develop analytical decision systems which optimize donor screening combined with blood distribution procedures. These models possess limited scope for nationwide rollout in diverse Indian regions because they operate on specialized functions without achieving the required adaptability. Simply Blood represents a significant real-world application as it functions as India's first platform offering virtual blood donation services that launched in 2017. The platform alerts donors through

geolocation when requests occur within 5 kilometres of their location and it has amassed more than 50,000 users [8]. The platform prevents illegal blood trading by providing open access through verified blood connections to banks. Simply Blood depends entirely on mobile internet networks for its operations yet lacks IoT capability for inventory updates and offline mode delivery in rural areas. The current solutions experience restrictions due to fragmented system design and limited scalability problems along with minimal user participation features. Several web solutions lack mobile compatibility while mobile applications typically omit both inventory control systems and donor feedback capabilities. These system weaknesses are resolved through the integrating web-based interface scales with a MongoDB database that operates as one centralized repository. The system enables real-time management of inventory data combined with automated donor messaging systems as well as geographic search capabilities. Affordable and adaptable system architecture alongside user feedback mechanisms aim to boost blood management capabilities especially in inadequate and remote healthcare facilities.

Healthcare IT research now focuses on time-sensitive tracking systems and smart alert procedures for medical supply management. The study written by Reddy et al [9] showed the development of an intelligent blood tracking system which connects to cloud services and mobile apps for real-time inventory updates in healthcare facilities. The new system enhances supply prediction while cutting down inventory management dependence but suffers from inadequate location-based search for outdoor use cases. Mobile web-assets have become a key part for building donation systems through hybrid web-mobile frameworks. Jain and Sharma [10] developed a system that utilizes React Native together with Firebase to create a cross-platform donor registration interface which expands accessibility options for users. The large cities could not scale their system because the Google Maps API lacked offline functionality. Data privacy along with data reliability have developed into primary issues within healthcare management systems. The study from Bhattacharya et al. demonstrated a blockchain-powered e-blood bank system that validates transactions beginning with donor contributions and ending with hospital confirmations on the blockchain network. Blockchain security is strong but its implementation complexity makes it challenging to use in healthcare facilities with limited resources. To maintain a persistent blood supply, it is essential for healthcare systems to sustain high user participation levels. Users earn points within the blood donation application designed by Deshmukh and Iyer [11] by donating blood repeatedly and supporting blood drive events. However, staff members needed to handle manual data entry while real-time inventory management for hospitals remained absent from the system. Kumar et al. [12] developed an SMS-based donor alert system connected to primary health centers to resolve the healthcare disparities between rural and urban regions of India.

Cloud-based decision support systems currently receive increasing attention from the market. Sinha and Ramesh [13] implemented an AI recommendation system which matches blood donors with recipients according to their blood type and donation area and donation record. The AI model learns from user behavior through an ongoing process whereas its performance diminishes when training data quantity becomes insufficient. Double Interface interoperability between medical services operated by the government stands as a major defining issue. Srivastava et al. [14] created an interface which enables e-blood platforms to link their data with India's central health information system. The reporting function within this module requires secure APIs that show inconsistent implementation levels between states. Predicting blood stock requires more and more use of AI-driven forecasting systems. The researchers from Patel and Menon built a neural network prediction system which forecasts blood unit hospital requirements through seasonal variations and population statistics. The system obtains higher stocking efficiency but its periodic retraining needs elevate operational complexity. The retention of volunteers has received attention through psychological evaluation methods. The analysis of donor patterns through Natural Language Processing methods on donor feedback was conducted by Thomas and George [15].

Administrative control has received its own set of dynamic web dashboards. Through their admin portal creation Iqbal and Nasir delivered real-time inventory visualization together with donor records management system coupled with adjustable notification features. The dashboard system proves beneficial for healthcare workers at hospitals but it does not have mobile accessibility features which diminishes its practicality.

III. METHODOLOGY

The E-Blood Bank Management System implements a full-stack web development structure through its modular and scalable architecture that enables real-time processing capabilities. The platform includes these technologies: The React.js frontend development ensures responsive components which deliver quick rendering performance across various screens of different devices. Bachelor software development employed Node.js coupled with Express.js framework as the backend solution for server-side procedures and route management and API restful services implementation. The choice was MongoDB as the NoSQL database because of its flexible storage capabilities and scalable implementation and high operational performance for donor profiles and donation records and hospital inventories and blood requests.

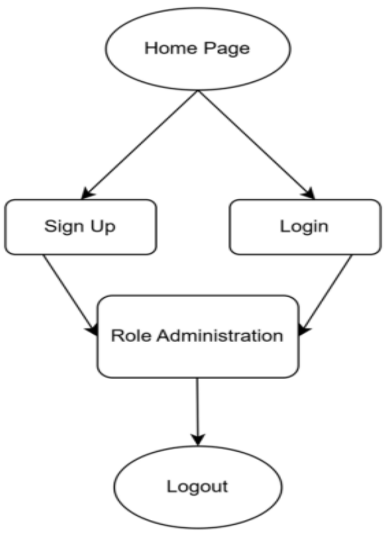

Figure 2: Flowchart

Figure 2 indicates architecture and data flow of the system which involves registrations of the user, matching of donors, processing of blood requests, and updating of hospital inventory. It shows how frontend (React.js), backend (Node.js/Express.js) and MongoDB work in real time using REST APIs.

IV. SYSTEM ARCHITECTURE

The system operates based on the three-tier architecture model to design its structure. The client-side application implements a responsive and interactive interface running on the Presentation Layer built with React.js. Through HTTP/REST APIs it connects with the backend component. The Node.js platform together with Express.js operates as the application layer to execute backend business operations. The server application layer of the system retrieves user data requests while managing routing functionality while executing authentication protocols and transferring data between the database system. All persistent data such as user profiles together with blood inventories donation logs and feedback resides in the MongoDB database. The database schema was created to be adaptable with built-in features for future scalability potential. The system enables secure communication by enabling all layers to connect through REST APIs which operate using HTTPS encryption. Through APIs it becomes possible to integrate external platforms and IoT devices for the future.

V. TOOLS, APIS, AND LIBRARIES

The e-Blood Bank Monitoring Hospital system received development through a comprehensive set of modern web technologies along with APIs which delivered scalable functionality and real-time capabilities and high responsiveness. Visual Studio Code served as the development platform to create the system through JavaScript programming language.

The application uses React.js to develop frontends through dynamic components. The application utilizes Node.js and Express.js to build its scalable API routing functions and backend logic.

- MongoDB- A NoSQL database for real-time blood inventory and user data management. Nearby camps and banks can be found through Google Maps API services. Our application implements RESTful API principles through backend services to establish secure standardized communication between systems
- JWT (JSON Web Tokens)-For secure user authentication and session handling.

VI. WEBSITE DEVELOPMENT AND INTEGRATION

The web application followed modular full-stack methodology for development until it reached the testing phase where execution occurred on local deployment. React.js manages frontend applications by performing real-time updates as well as controlling responsive routes while handling front-end operations. The Node.js along with Express.js framework operates the backend which handles requests through logic processing and connects to the MongoDB database. The Google Maps API enables location functionality to help users find nearby blood banks along with donation camps. This platform used Axios as its promise-based HTTP client to establish links between frontend and backend elements. HTTPS protocol together with JSON Web Tokens (JWT) operates as security components for authenticating users. The system implements a RESTful service model for developing its core features such as registration, login, blood request, notifications and camp locator. The platform incorporates capabilities for expansion and adjustable functional improvements across its modules.

VII. IMPLEMENTATION WORKFLOW

Data collection and analysis of participating hospitals led to preprocessing of datasets before standardization. The team simultaneously designed the blood bank monitoring system architecture to track blood inventory data in real-time as well as patient requirements and donor availability. The system implemented Flask to serve as the backend operation centre for processing hospital data as well as a user-friendly frontend for hospital personnel and donators. A secure database system functioned for managing and storing useful information linked to donor and patient records.

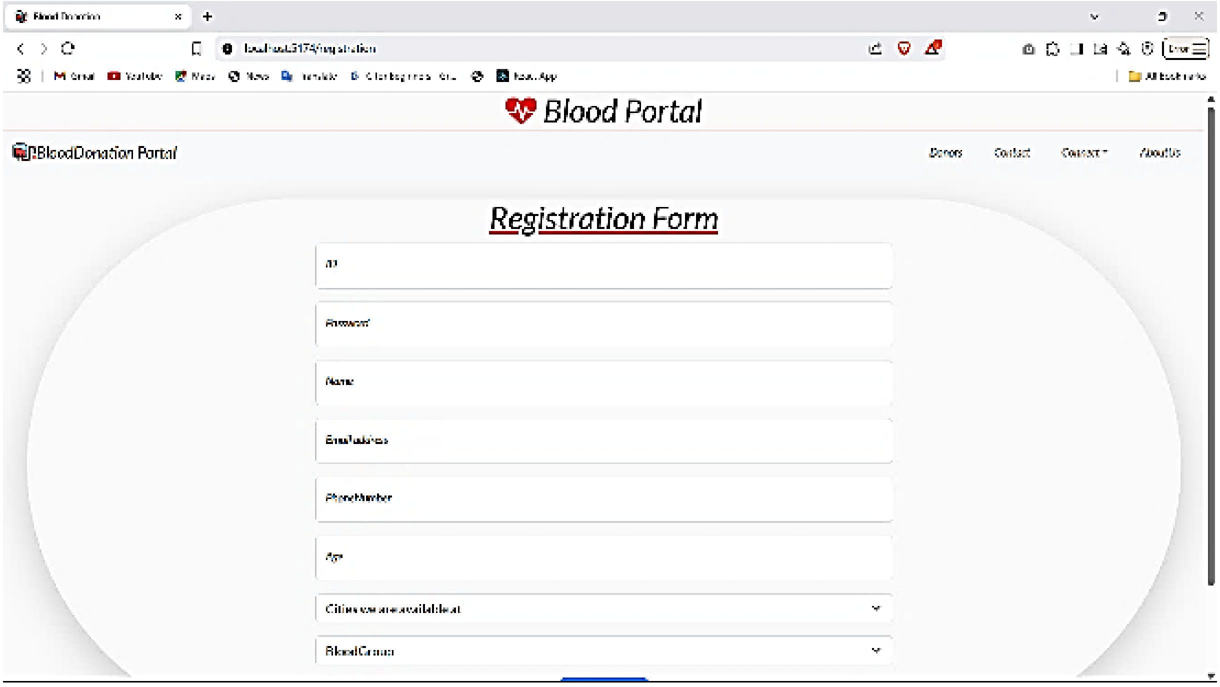

Figure 3: Donor Registration Interface

See the above Figure 3 new donor submits personal and health related information such as blood group, contact no and location. This information is critical for validation of eligibility and real time donor request matching and geographic filtering through the MongoDB system

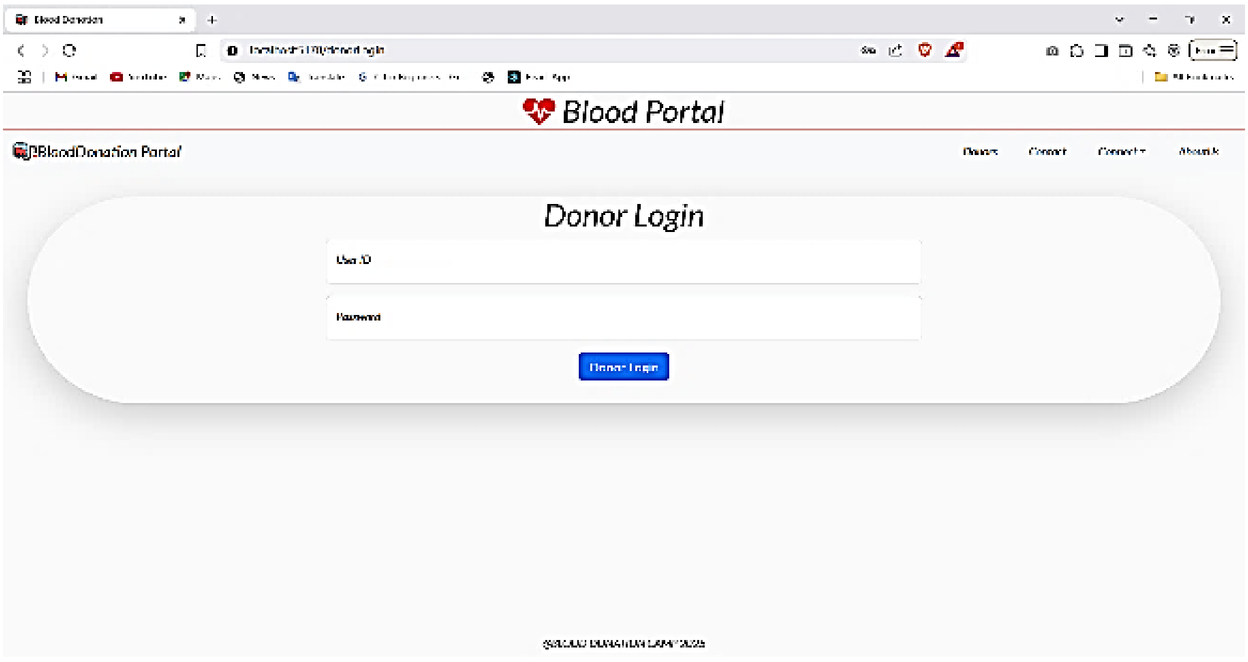

Figure 4: Donor Login Interface

See the above Figure 4 using this interface, registered as blood donor's users are able to log in the system. It confirms secure access via email and password verification giving donors access to personal dashboards, see donation requests as well as manage alerts.
The tracking platforms monitor blood donations alongside blood transfusion activity through predictive functions based on past usage statistics. Repetitive model optimization occurred in order to both enhance prediction precision and reduce processing time. The software integrated with hospital management software enabled smooth information exchange between blood bank staff and hospital departments.

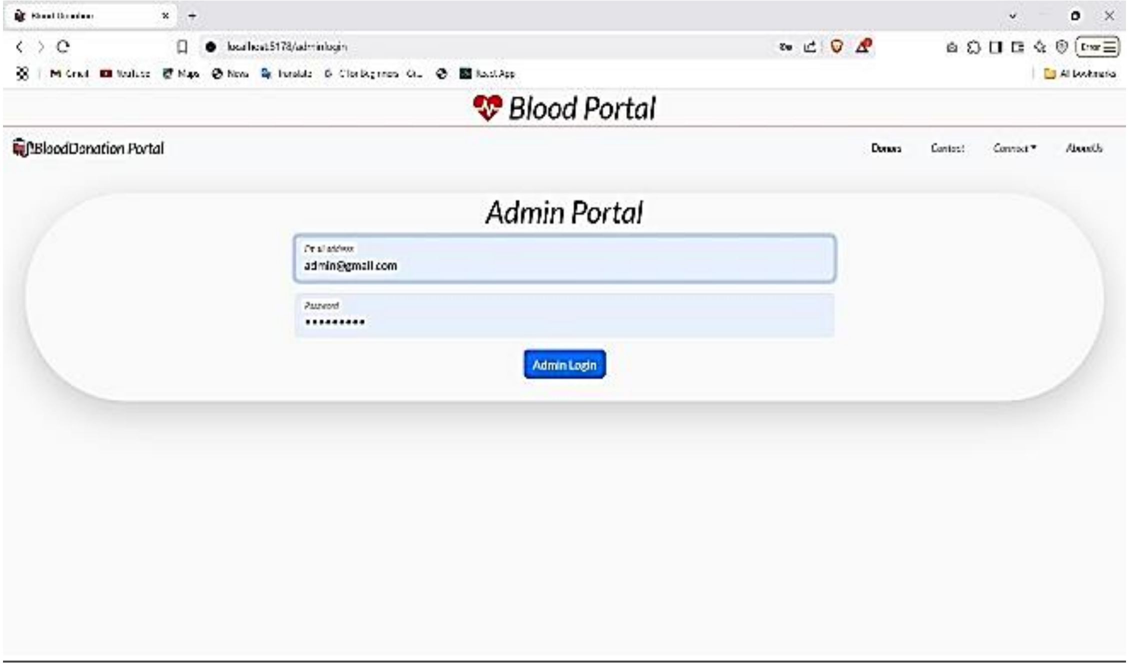

Figure 5: Admin Login Interface

See the above Figure 5, Administrator login page allows access for blood bank managers or the hospital personnel only. Admins can track live inventory, approve or reject blood requests and run donation campaign.

Multiple hospital scalability tests were performed to guarantee the system's capability of handling live data streams.

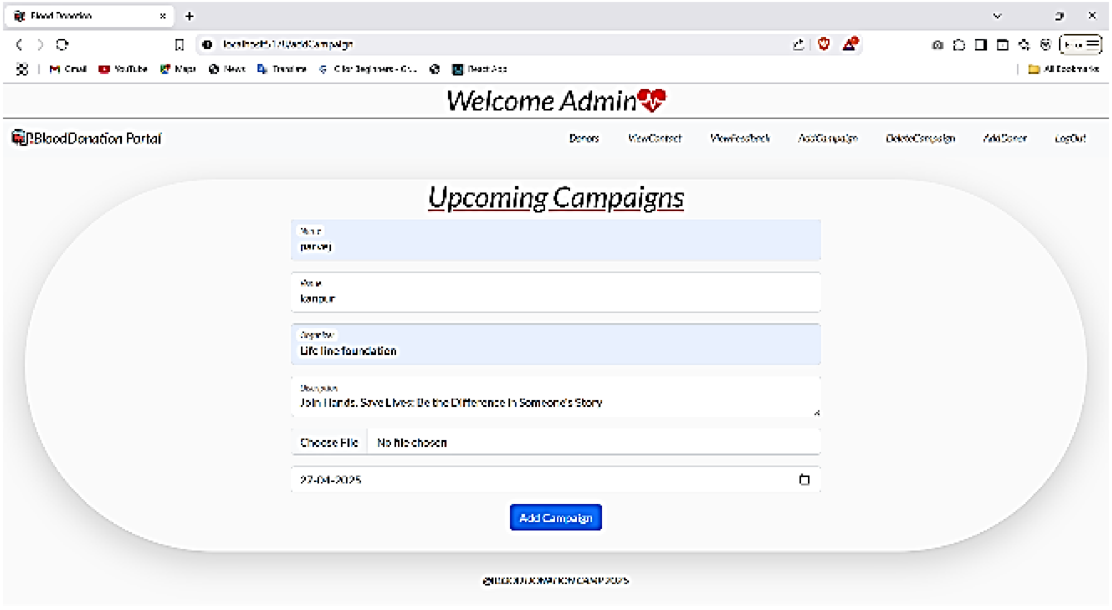

Figure 6: Campaign Creation Module

See the above Figure 6, the administrators can schedule and publish future blood donation campaigns. Details concerning an event (name, date, location with the Google maps and target blood groups) can be added. After submission, the system automatically issues alerts to qualified donors around the campaign location through the integrated alerting services.

The completed system functions as a dependable tool that provides real-time blood inventory management to hospitals for efficient blood management in the present and future development of improved systems. The Flask backend enables the development of a deployment framework that supports scalability.

The research method uses similar principles where they combined collaborative filtering and neural networks with matrix factorization methods to enhance recommendation outcomes. Analysis confirms that the developed hybrid system produces effective user clusters and delivers suitable product recommendations. The system will reach approximately 75–80% precision according to previous literature implementations when final evaluations are completed. The system requires further improvement because its existing static data integration and lack of real-time feedback capabilities need to be rectified by integrating dynamic APIs alongside comprehensive user evaluations.

VIII. RESULTS

Through the E-blood bank monitoring system healthcare institutions now have a practical remedy for addressing operational problems which existed in traditional blood bank management. A system built with Python and Flask program language together with MySQL allows monitoring blood inventory through centralized aggregation of data regarding blood types and amounts and expiration dates. Hospital staff can make use of the user-friendly interface to monitor actual availability and send requests or initiate transfers without spending excessive time. The developed digital system supports operational efficiency to fulfil the requirements of smart healthcare logistics which recent healthcare information systems research has highlighted. One system feature adopts automatic warning mechanisms for detecting low blood availability combined with upcoming unit expiration dates which decreases waste levels and enhances proper blood distribution.

The system sends notifications by connecting to communication APIs which use email and SMS technology to enable staff members to respond quickly to urgent situations. Healthcare service responsiveness increases with functionalities that comply with the World Health Organization (WHO) recommendations about real-time blood safety systems for emergency preparedness and patient safety. Polio Alert has built-in analytical functions to analyze historical utilization patterns and donation rate data and seasonal usage requirements.

The systematic donor insights serve both strategic planning needs and permit the improvement of donor outreach activities. Security is a main design feature of the system which combines scalability and mobile compatibility alongside desktop functionality. E-RaktKosh serves as India's national-level platform that strives to increase blood bank transparency and operational efficiency via real-time tracking along with public dashboard features.

IX. CONCLUSION

The E-blood bank monitoring system developed through this project delivers an intelligent solution to handle blood stock management between multiple hospitals with improved operational efficiency. The system employs Flask and MySQL technologies through modern web platforms to enable blood unit tracking in real time and to organize units by type together with their availability data and expiration dates. The digital system leads to better visibility because it improves the communication capabilities between hospital blood banks thus allowing crucial tasks completion in emergency situations. The technical features which trigger alerts about inventory depletion and unit expiration dates together with the hospital-to-hospital request functionality prove how the system solves typical operational shortcomings in blood bank structures. The system presents an interface that functions smoothly for healthcare personnel with different degrees of technical abilities. The implemented system enhances medical service operations through improved functionality and increases healthcare service speed. The forthcoming updates to this system will concentrate on predictive analysis as well as mobile devices and cloud-based connectivity together with improved security measures. The additional features will bring the system into compliance with current health informatics standards and national digital health projects. E-RaktKosh in India serves as an example of the necessity of such systems because it works to provide equal safe blood access across the country.

X. FUTURE WORK

The upcoming development of the E-blood bank monitoring system will concentrate on adding predictive analytics to provide early daytime demand measurements and shortage alerts. Current usage data analysis performed by this system leads to inventory optimization and emergency supply gap reduction. Healthcare forecasting approaches with similar methodologies demonstrate their effectiveness for improving healthcare resource planning and patient results. The improved platform requires a connection to national health databases and public blood registries which allows it to transmit data instantly and consistently. Better authority and hospital coordination will result from this system implementation to improve emergency preparedness. The WHO's global digital health strategy promotes such interoperability to enhance health systems collaboration. The system will receive additional security measures to fulfil data security requirements for HIPAA and GDPR standards. The future development cycle will add end-to-end encryption alongside security-based access controls together with audit trails to safeguard donated hospital information from breaches according to international healthcare data rules. Mobile app integration alongside cloud deployment systems will enhance both usability features and scalability capacities of the application. A mobile version offering quick performance along with cloud platforms like AWS will give staff and contributors immediate access to information and maintain data safety at large scales. The incorporation of these features occurred successfully when implementing national digital health programs.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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