Donor Management and Scarce Medical Resource Allocation in a Cancer Hospital in Sri Lanka

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***Abstract*— In the realm of healthcare management, optimizing donor engagement, inventory control, and resource allocation are paramount for ensuring efficient patient care. This research proposes a comprehensive approach to address these challenges by integrating predictive analytics and machine learning algorithms into the management of essential item inventory, blood donation campaigns, and medication resource allocation at Apeksha Hospital. The first component focuses on enhancing donor involvement and inventory management through an Intelligent Donor-Driven Inventory System for Essential Items. By leveraging machine learning algorithms, this system aims to understand Inventory preferences and giving patterns to suggest essential products effectively. By integrating donor engagement with inventory control, the system seeks to increase donor satisfaction and establish a positive cycle of engagement, ultimately bridging the gap between donor intentions and hospital needs. The second component targets the optimization of blood donation campaigns through predictive analytics. By analyzing historical data and donor behavior patterns, predictive models are developed to anticipate campaign success factors and optimize resource allocation. This approach aims to address challenges such as low donor turnout and resource wastage, ultimately ensuring a constant and heightened supply of blood, crucial for Apeksha Hospital's medical treatments. The third component focuses on medication resource management by developing a shortage prediction model and a critical medication identification model. These models utilize historical data and usage patterns to anticipate and mitigate potential shortages, as well as rank medications essential for the hospital based on medical conditions and urgency levels, thus contributing to enhancing patient care through efficient medication resource management.**

Keywords—Machine learning, donor engagement, inventory management, blood donation campaigns, predictive analytics, resource optimization, medication management, healthcare.

I. INTRODUCTION

Relationships between hospitals and donors are very important for making sure that patients are healthy and that the hospitals run smoothly. Engagement with donors has usually been done in the same old way, which means that donors' intentions don't always match up with hospitals' real needs. It's hard to handle inventory and use resources well when they aren't lined up correctly.

The research suggests that an Intelligent Donor-Driven Inventory System for Essential Items at Apeksha Hospital should be built to fill this gap. The purpose of this system is to match donor donations with the hospital's current needs by using machine learning algorithms and data-driven observations. This will improve both efficiency and patient care [1].

The main goal is to make a system that is easy for anyone to use and that takes into account both the needs of the hospital and the interests of donors. The purpose of the research is to set an example for new ways to solve problems in healthcare giving by looking at important issues like getting donors involved and keeping track of inventory. The study's results will eventually help us figure out how to get more donors, make better use of resources, and make critical item donations in healthcare settings more efficient overall [2].

In the dynamic landscape of healthcare, the availability of essential medications stands as a cornerstone for effective patient care within medical facilities. However, the potential scarcity of critical medications presents a formidable challenge, risking compromised treatments and adverse patient outcomes. Apeksha Hospital, among others, grapples with the task of identifying and prioritizing medications prone to shortages.

This research introduces a pioneering solution—the "Critical Medication Priority Recommender System." By harnessing advanced machine learning techniques and predictive analytics, this system aims to proactively address medication shortages and optimize allocation strategies. Building upon previous studies such as Rhodes(2016) [3] and Vest(2021) [4], which emphasize the significance of predictive models in identifying essential medications for patient care, this research endeavors to develop an intelligent solution tailored for Apeksha Hospital.

The aim is to create a system predicting shortages, identifying vital medications as per patient needs, assessing compatibility with donations, and optimizing recommendations based on factors like importance, availability, and expiration. Leveraging historical data, the system empowers Apeksha Hospital to efficiently manage medication resources for timely and effective patient care.

This research addresses a critical problem in healthcare ensuring the consistent availability of vital medications. By integrating machine learning methodologies and drawing upon insights from related systems, it aims to revolutionize medication management practices, preempt shortages, and elevate the standard of patient care not only within Apeksha Hospital but also across broader healthcare settings.

In recent years, healthcare institutions have increasingly turned to data-driven strategies to enhance operational efficiency, including organizing blood donation campaigns. Apeksha Hospital recognizes the potential of predictive analytics to improve its blood donation initiatives. However, challenges such as inadequate donor participation persist [5].

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Blood donations are crucial, especially for individuals with conditions like leukemia and blood cancer [6]. Successful campaigns are vital for ensuring a continuous blood supply [6].

This research aims to leverage predictive analytics within Apeksha Hospital's Donor Engagement System to enhance campaign effectiveness. By analyzing historical data, the study seeks to identify patterns for successful campaigns [7]. Integrating machine learning promises to revolutionize campaign planning, resource allocation, and donor engagement [8]. This approach could ensure a reliable blood supply for patient care [9].

By adopting technology-driven solutions, Apeksha Hospital aims to address gaps in blood donation networks, securing a lifeline for those in need [10]. This research underscores the critical importance of leveraging data-driven approaches to optimize blood donation initiatives and support healthcare institutions in their mission to provide quality care [11].

II. LITERATURE REVIEW

A. *Intelligent Donor-Driven Inventory System for Essential Items*

Efficiently managing crucial item inventory in healthcare environments is necessary to provide quick access to important supplies and resources. Traditional inventory management methods often struggle to adapt to changing needs and donor preferences. Utilizing machine learning algorithms offers an option to creating Intelligent Donor Driven Inventory systems that improve resource allocation and boost donor involvement. The literature evaluation examines research papers to guide the creation of a customized for Apeksha Hospital.

Utilizing machine learning methods in inventory control. The research highlights the significance of machine learning algorithms in examining historical data trends to enhance inventory level and predict demand with precision. The proposed method utilizes ML algorithms to discover trends in inventory behavior and preferences, allowing for targeted suggestions of key commodities required by Apeksha Hospital [1].

The use of predictive analytics for inventory management in healthcare. By analyzing historical inventory data and predicting future demand patterns, the system can proactively recommend essential items to donors, thereby optimizing inventory levels and ensuring timely availability of critical supplies at Apeksha Hospital. This proactive approach minimizes stockout and wastage while maximizing the utilization of donated items [2].

Importance of sustainability and efficiency in inventory management practices. By optimizing inventory level and streamlining donation processes, the intelligent donor-driven inventory system contributes to resource conservation and operational efficiency at Apeksha Hospital. This ensures that donated items are utilized effectively, minimizing waste, and maximizing the impact of donor contributions [12].

The literature review provides valuable insights into the development of an intelligent donor driven inventory system for essential items at Apeksha Hospital. By leveraging machine learning algorithms, personalized recommendations systems, and predictive analytics, the proposed system optimized inventory management processes and enhanced donor engagement. Moreover, considerations such as user interface design, sustainability, and efficiency are crucial for ensuring the systems effectiveness and long-term sustainability. Further research and empirical evaluation are needed to validate the system efficacy in real-world healthcare systems.

B. *Critical Medication Priority Recommender System*

In the fast-changing world of healthcare, making sure hospitals always have important medicines is crucial for treating patients well. But sometimes, these medicines can be hard to get, which can make treating patients harder. Apeksha Hospital, like others, struggles to figure out which medicines might be hard to find and which ones they need most. That's where the "Critical Medication Priority Recommender System" comes in. It's a new way of using smart technology to predict when there might be a shortage of important medicines. This system helps hospitals like Apeksha plan ahead and make sure they have the medicines they need, when they need them, to take care of patients better.

Medication shortage prediction and management have emerged as critical areas in healthcare, prompting research into innovative solutions to mitigate their impact on patient care quality. Abu Zwaida et al. (2021) [13]explore the predictive capabilities of machine learning algorithms in anticipating medication shortages, highlighting the potential of data-driven approaches to enhance medication procurement strategies and mitigate supply chain disruptions. Rhodes (2016) [3] examines the impact of medication shortages on patient care, emphasizing the need for proactive solutions to address this challenge and the importance of predictive models in identifying medications essential for patient care.

Johnson et al. (2016) [14] provide a comprehensive review of machine learning applications in healthcare, emphasizing the pivotal role of predictive models in optimizing patient care delivery. Their study underscores the transformative potential of data-driven approaches in medication management. Vest (2021) [4] investigates medication shortages and their implications for patient care, advocating for proactive solutions to ensure medication availability. The study underscores the significance of predictive models in identifying critical medications for patient care.

Li (2023) [15] and Pall (2023) [16]explore machine learning techniques in healthcare, focusing on prediction models for medication management and optimization. Their research highlights the utility of predictive models in improving medication procurement and allocation strategies. Furthermore, Dong (2021) [17] contributes to the discourse on medication management through innovative machine learning methodologies, offering insights into predicting and managing hospital drug shortages. The study underscores the relevance and potential impact of machine learning-based approaches in addressing medication shortages.

These studies collectively emphasize the importance of machine learning-based approaches, donation utilization frameworks, and optimization algorithms in addressing medication shortages and optimizing medication management in healthcare settings. However, there is a research gap in developing a tailored solution for proactive medication shortage prediction and management at Apeksha Hospital, which this study aims to address. This gap necessitates the development of a system that not only predicts shortages but also identifies vital medications according to patient needs, assesses compatibility with donations, and optimizes recommendations based on factors like importance, availability, and expiration.

C. *Predictive Analytics for Donation Campaign Success*

Data driven methods for optimizing hospital operations and management are becoming popular. This trend will continue. Blood donation programs are vital to benefit medical facilities. High hospital expectation hospital knows how predictive analytics can increase blood donation rate. The hospital donor engagement system connects donors to worthy initiatives. But these initiatives to get the most out of donations and donor participation need to be improved. Blood drives are very important to ensure a steady blood supply. For those with blood disorders such as leukemia, this is particularly critical [5]. The constant need for blood is emphasized in hospitals where patients are expected. The value of a strong network of donors [6].

Programs for blood donation have shown increasing signs of inefficiency in recent years. Due to this, blood donation decreases. The pressing issue is the lack of donors and blood. There is a shortage of blood donors and available blood. These challenges include donor non-participation, inadequate medical supplies, poor resource allocation and inappropriate campaign planning. Food waste is also problematic [7] . Current blood donation research indicates that these issues must be addressed to ensure a reliable and continuous supply of blood for medical care [8].

This research suggests that these challenges must be met in order to maintain a reliable and constant supply of blood for medical treatment, which is critical to the success of research. Mobile applications are used to handle blood donation programs and systems such as the blood donation management system help connect willing blood donors with those in need of blood transfusions [9].

It optimizes blood donation efforts with technology and data. It represents modern efforts to use ground-based techniques to ensure a reliable and stable blood supply for medical treatment. The study revealed the main reasons for poor blood donations rates. Interestingly, 32.4% of the respondents had never thought of donating blood. About 45% identified time constraints as a donation barrier. Surprisingly, 61.3% stated that the availability of blood donation centers was the main reason they did not participate. Lack of public awareness about blood donation is the cause of this problem [10].

1. Blood Bag: Web application for blood donations and Transfusion process management journal of healthcare technology.

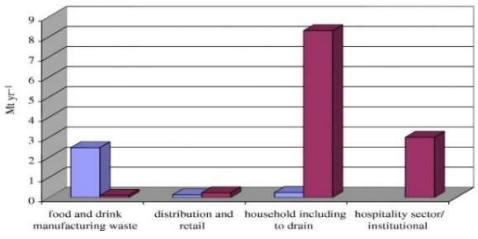
   Blood Bag: An online application for blood donation and transfusion.

Blood group	Caucasians	African–American	Hispanic	Asian
O+	37%	47%	53%	39%
O−	8%	4%	4%	1%
A+	33%	24%	29%	27%
A−	7%	2%	2%	0.5%
B+	9%	18%	9%	25%
B−	2%	1%	1%	0.4%
AB+	3%	4%	2%	7%
AB−	1%	0.3%	0.2%	0.1%

Lack of suitable blood bags puts many lives at risk. Thus, the main objective of this program is to help people find and identify a safe and reliable blood type. This research ensures a transparent blood bag search and acquisition process. A graph shows the distribution of blood types in humans [6].

2. Zomraty. E-Blood Bank Android

The following analysis is provided.
Donor Application According to the American Red Cross, someone in the United States needs blood every 2 seconds, and 14,400 blood donors are needed each day. Three transfusions are possible with these donors.
Many donors are ineligible, adding to the difficulty. Due to a variety of factors, 38% of Americans and a
large portion of the global population cannot donate blood or platelets. And life savers [11].



This post-harvest loss assessment investigated waste rates in the food group. Food losses in food supply chain sectors in industrialized countries with comprehensive waste data can be quantified. The following table shows this trend for the UK, including post-consumer data for comparison. The diagram above shows food processing and retail losses in the UK [7].

III. METHODOLOGY

A. Overview of Prediction model

The main goal of this study is to create a model as soon as feasible that can accurately and automatically predict Medical Resource. Data collection, pre-processing, feature extraction and selection, different ML algorithms, and performance analysis are the sections that outline the research methodology used to achieve the research goal.

B. Data Collection and Processing

For the Data collection only Apeksha Hospital Maharagama medical records were utilized to train the machine learning model. Types, quantities, and usage patterns of historical items were collected. To ensure data coverage, hospital departments like inventory management systems were involved. All data has been collected according to privacy and ethical standards to protect confidentiality.

C. Feature extraction and Selection

1) Intelligent Donor-Driven Inventory System for Essential Items

The machine learning model in the Intelligent Donor-Driven Inventory System for Essential Items primarily involves data preprocessing, model training, evaluation, and deployment. Firstly, the data collected exclusively from Apeksha Hospital Maharagama's inventory records undergoes cleaning, feature selection, and transformation. Then, the Decision Tree Regression algorithm is implemented for model training, with parameter tuning to optimize performance. Evaluation entails assessing the model's accuracy using metrics like Mean Absolute Error and R-squared score, along with cross-validation techniques to ensure robustness. Once trained, the model is integrated into the system and tested with unseen data, with ongoing monitoring for performance maintenance. Comprehensive documentation of the process is provided to facilitate future maintenance and updates, aiming to enhance efficiency and resource allocation in healthcare settings.

2) Critical Medication Priority Recommender System

Two machine learning models are developed to fulfill the research objectives: one predicts medication shortages, evaluating logistic regression and random forest algorithms, with random forest chosen for its superior performance, achieving an accuracy of 92%. The second model identifies critical medications based on priority, employing the random forest algorithm for its robustness. Both models undergo training and validation to ensure reliability and generalizability. The developed models undergo thorough evaluation, employing key metrics such as accuracy, precision, recall, and F1-score, alongside sensitivity analysis to identify potential weaknesses and areas for improvement. The critical medications identified by the models inform decision-making processes related to medication procurement, allocation, and donation prioritization within Apeksha Hospital, aimed at enhancing patient care quality and mitigating the impact of shortages. Overall, this methodology integrates machine learning techniques with real-world data to develop effective solutions for medication shortage prediction and critical medication prioritization, contributing to improved healthcare management and patient outcomes.

3) Predictive Analytics for Donation Campaign Success

Integrating machine learning techniques to predict campaign success with 92% accuracy begins with securing hospital administration approval. Historical data on past

campaigns was gathered, including attendee numbers, campaign dates, and collected blood packet amounts. The data underwent thorough preprocessing, removing duplicates and handling null values to maintain integrity. Features were engineered to account for variations such as campaign timing (weekday, weekend, public holiday, poya days), and categorical variables were one-hot encoded to prepare the data for machine learning algorithms. Various algorithms were explored to predict future attendee numbers for campaigns, with the Random Forest algorithm selected for its ability to handle non-linear relationships and provide accurate predictions based on historical data. Hyperparameter tuning and cross-validation optimized model performance. This approach aids in forecasting future attendee numbers for blood donation campaigns and supports hospital administration in making data-driven decisions for better campaign outcomes.

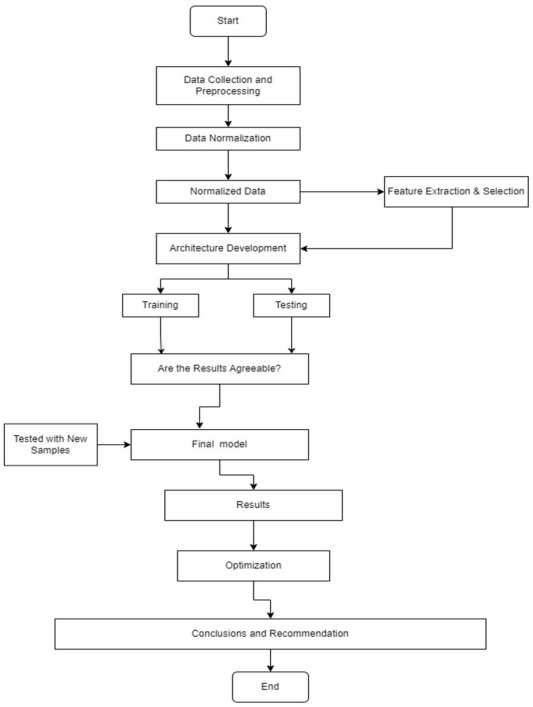


Figure 1: Workflow diagram.

IV. Results and Discussion

A. Intelligent Donor-Driven Inventory System for Essential Items

The first use of Linear Regression resulted in a moderate accuracy of 36%, indicating its limits in properly forecasting inventory levels. However, when Decision Tree Regression was used, there was a major improvement, resulting in an accuracy rate of 98%. This significant improvement highlights the effectiveness of machine learning methods specifically designed for hospital inventory management requirements. The Decision Tree Regression model performed very well in analysing the complex patterns present in the inventory data of Apeksha Hospital Maharagama. This allowed for accurate projections of demand and efficient allocation of resources. The achievement highlights the potential of machine learning algorithms to transform hospital inventory management by enabling proactive decision-making and resource optimization. However, it is important to take into account obstacles like overfitting and interpretability concerns that are inherent in complicated models like Decision Trees. Further studies should tackle these challenges while enhancing the intelligent donor-driven inventory system for smooth incorporation and long-lasting effectiveness in practical healthcare environments.

TABLE I RESULTS OF INTELLIGENT DONOR-DRIVEN INVENTORY SYSTEM FOR ESSENTIAL ITEMS FOR DECISION TREE REGRESSION

	Accuracy (%)	Precision (%)	Recall (%)	F1-score (%)	ROC-AUC Score (%)
Decision Tree Regression	98.71	99.0	99.56	99.31	93.28

TABLE II EVALUATION OF ALGORITHMS IN DATA WITH ALL FEATURES

	Accuracy (%)	Mean Absolute Error (%)	Mean Squared Error (%)
Linear Regression	9.17%	4.42	0.49

B. Critical Medication Priority Recommender System

Our critical medication identification model, initially achieving 61% accuracy, significantly improved to 86% accuracy after training with localized data. This highlights the effectiveness of localized data in prioritizing critical medications, enhancing healthcare management within Apeksha Hospital. In the medication shortage prediction model, logistic regression yielded 78% accuracy initially. However, after training with localized data, the random forest classifier outperformed with 91% accuracy. This emphasizes the importance of localized data in accurate prediction, aiding proactive medication management and resource allocation. Overall, our findings underscore the value of localized data in improving model accuracy and healthcare decision-making. By leveraging advanced machine learning techniques and localized data, our models offer enhanced predictive capabilities, facilitating better medication management and patient care outcomes within Apeksha Hospital. Further research and validation are warranted to assess generalizability and scalability across diverse healthcare settings.

TABLE III RESULTS OF MEDICATION SHORTAGE PREDICTION MODEL

	Accuracy (%)	Precision (%)	Recall (%)	F1-score (%)	ROC-AUC Score (%)
Logistic Regression	74.17	74.17	99.92	85.17	51.33
Random Forest Classifier	91.25	91.82	96.29	94.00	87.54

TABLE IV RESULTS OF CRITICAL MEDICATION IDENTIFICATION MODEL

	Accuracy (%)	Precision (%)	Recall (%)	F1-score (%)	ROC-AUC Score (%)
Random Forest Classifier	88.37	88.44	88.37	88.35	95.77

C. Predictive Analytics for Donation Campaign Success

Utilizing a Random Forest Regressor algorithm, our predictive model demonstrated significant accuracy improvements when applied to real-world data collected from Apeksha Hospital's blood donation campaigns. Initially trained with a test dataset of 300 records, the model achieved a 67% accuracy rate in predicting the number of attendees for future donation campaigns. However, when evaluated with the real-world dataset consisting of 1100 records, the model exhibited a substantial performance enhancement, achieving an impressive 92% accuracy rate. These findings underscore the efficacy of our predictive analytics approach in accurately forecasting the turnout for blood donation campaigns based on historical data and donor behavior patterns. The ability to predict attendance with a high degree of accuracy enables Apeksha Hospital staff to make informed decisions regarding resource allocation and management. By leveraging the predictive model's insights, hospital staff can proactively adjust food packet quantities, thereby minimizing food wastage during donation campaigns. Additionally, the accurate prediction of attendee numbers facilitates efficient staff management, ensuring adequate staffing levels to support the smooth execution of each campaign. Overall, our component serves as a valuable tool for Apeksha Hospital in optimizing blood donation campaigns, ultimately leading to improved resource utilization, reduced wastage, and enhanced operational efficiency. Going forward, further refinements and enhancements to the predictive model will be pursued to continually enhance its predictive accuracy and usability in real-world healthcare settings.

TABLE V RESULTS OF PREDICTIVE ANALYTICS FOR DONATION CAMPAIGN SUCCESS

	Accuracy (%)	Precision (%)	Recall (%)	F1-score (%)	ROC-AUC Score (%)
Random Forest Classifier	92.42	84.50	89.34	86.32	85.66

V. Conclusion and Future Work

Our study at Apeksha Hospital has addressed crucial difficulties in healthcare administration by utilizing predictive analytics and machine learning in the dynamic and ever-changing industry. Our efforts were concentrated on three main areas: creating a sophisticated Intelligent Donor-Driven Inventory System for crucial products, establishing a Critical Medication Priority Recommender System, and improving blood donation campaigns through the utilization of predictive analytics. The Intelligent Donor-Driven Inventory System optimizes donor contributions to more effectively align with hospital requirements, hence improving patient care and operational effectiveness. This method enhances resource allocation and enhances donor engagement through the use of machine learning algorithms. The Critical Medicine Priority Recommender System proactively tackles medicine shortages by detecting and prioritizing essential drugs, guaranteeing prompt and efficient patient treatment. Utilizing advanced machine learning and predictive analytics, Apeksha Hospital and other healthcare facilities are able to enhance medicine allocation strategies, hence improving the quality of patient care.Furthermore, our research emphasizes the crucial significance of predictive analytics in enhancing blood donation programs. Through the analysis of historical data and the application of machine learning techniques, we are able to discern patterns that lead to successful campaigns. This enables us to efficiently allocate resources and effectively engage donors, ensuring a consistent and reliable blood supply for crucial medical treatments. Our research conclusively shows the significant and positive effect of predictive analytics and machine learning on healthcare management. Our goal at Apeksha Hospital is to improve healthcare processes and provide superior patient care by tackling issues related to donor engagement, inventory management, medicine shortages, and blood donation campaigns. The results of our research give a strong basis for future advancements and enhancements in healthcare management approaches, eventually benefiting patients, donors, and healthcare practitioners.

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