A Blood Bank Information System for the Ministry of Health of Kenya

Student ID: 101493

Group: 4B

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Declaration

I declare that this work has not been previously submitted and approved for the award of a Bachelor's degree by this or any other University. To the best of my knowledge and belief, the proposal contains no material previously published or written by another person except where due reference is made in the proposal itself.

Student's signature:

……………………………….………….. [*Signature*]

……………………………….………….. [*Date*]

Approval

The Information System Project 2 proposal of ………………………. was reviewed and approved *(for examination)* by:

Supervisor's signature:

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Abstract

Blood is one of the most critical elements and is referred to as river of life. It is common to hear of emergency situations where individuals require blood. The Kenya National Blood Transfusion Service (KNBTS) is the institution mandated by the Kenyan Ministry of Health (MoH) to coordinate and manage the national blood transfusion programme. Blood has a short shelf life of 35 days and its demand is always high, therefore the challenge comes in when trying to endure its constant supply. Kenya is facing a shortage of blood supplies in its hospitals, and blood banks with relatives and friends of patients increasingly having to put out calls for people to donate. This project addresses the problem facing Kenyan blood banks which is the lack of computerized technology and sustainable blood donation strategies to perform all its duties, one of which is to monitor and evaluate the standards in respect of blood donation, processing, movement and distribution of blood for the purpose of efficient blood transfusion. Developing a system to support donation, processing, and distribution of blood as well movement of blood is a solution the project aims to implement. It applies the Prototype Methodology since the approach can be used for development of a user interface of different applications independently of the type – desktop, web-based, mobile. The user interface is crucial in the development of software applications. If it is well designed it could help users to achieve their goals, to satisfy them and to encourage them to use the system. Software prototypes support development teams to explore usability, usefulness, and acceptability of their projects. The solution has been developed to be both mobile and web based. The data will be stored through MySQL DBMS because it is a user-friendly GUI that contains clients such as PHPMyAdmin which the project intends to use to store data.

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List of Abbreviations

Admin	Administrator
AIDS	Acquired Immune Deficiency Syndrome
AMRO	Association of Medical Reporting Organizations
BBIS	Blood Bank Information System
BTS	Blood transfusion services
CBIS	Computer-Based Information System
CDC	Centers for Disease Control
DBMS	Database Management System
DFD	Data Flow Diagrams
EDT	Electronic data transfer
ERD	Entity relationship diagram
FRD	Family Replacement Donors
GPRS	General Packet Radio Service
GUI	Graphical User Interface
HIV	Human Immunodeficiency Virus
HSV	Herpes Simplex Virus
HTML5	Hyper Text Markup language 5
ICT	Information and Communication Technology
ID	Identity Card
IDE	Integrated Development Environment
IEEE	Institute of Electrical and Electronics Engineers
KNBTS	Kenya National Blood Transfusion Service
KNH	Kenyatta National Hospital
MoH	Ministry of Health

MYSQL	My Structured Query Language
NBTS	National Blood Transfusion Service
PAHO	Pan American Health Organization
PC	Personal Computer
Pepfar	Plan for Aids Relief
PHP	Hypertext Preprocessor
QR	Quick Response
RBTC	Regional Blood transfusion Centers
RFID	Radio Frequency Identification
SMS	Short Message Service
SSAD	Structured Systems Analysis and Design
TTI	Transfusion Transmissible Infections
US	United States
USSD	Unstructured Supplementary Service Data
VNRBD	Voluntary Non-Remunerated Blood Donors
WHO	World Health Organizations

Chapter 1: Introduction

1.1 Background

The interest in blood and blood products in many nations keeps on expanding in view of the ascent in human life expectancy and the usage of new and aggressive surgical and therapeutic techniques requiring huge amounts of blood and blood products (Marantidou et al., 2007). Yet in developing countries which make up more than 50% of the world's population donate less than 50% of the total donations (World Health Organization, 2019). Blood donation and transfusion service involves collecting, processing, storing, and providing human blood intended for transfusion, performing pre-transfusion testing and finally, infusing into a patient (LI, Chao, and Don, 2006).

Concerns over blood shortage in Kenya hit headlines in the year 2019 after several counties reported severe shortage, with the blame being directed towards the Kenya National Blood Transfusion Service (KNBTS) which has been Kenya's only blood bank, collecting, testing, processing and distributing blood and blood products to all transfusing hospitals in Kenya (Muriuki, 2020). The claims have been proven right when Health CS Mutahi Kagwe acknowledged receiving reports on the illegal sale of blood in the country with KNBTS officers being the key suspect.

Currently Kenya has six centralized blood banks throughout the country known as Regional Blood transfusion Centers (RBTC) (Wakaria et al., 2017). A situation is frequently encountered where some banks have more demand than they can satisfy while in other banks the blood overstays and is eventually declared unfit for transmission resulting in wastage of the valued commodity. There are no synchronized records of blood availability in Kenya at any given point in time and the procedure of undergoing blood transfusion in Kenya is not an easy one since most patients have to source for blood in the event the hospitals lack blood of their type. Most patients have been forced to summon friends and relatives to donate blood for them of which according to the United States Department of Health, (2005) is unadvisable due to high number of infection cases (Nzoka & Ananda, 2014).

In 2018, 77% of people who donated blood were first-time donors. Repeat blood donors are better as they ensure a regular supply of blood and reduce the cost and effort involved in trying to find first-time donors (Mwai, 2020).

Information and Communication Technology (ICT) has had a big impact on health in countries that have already adopted it. In many if not all developed countries, the

National Blood Transfusion Service (NBTS) has an integrated blood and donor system (Ireri, 2014).

1.2 Problem Statement

The Directorate of Criminal Investigations in Kenya is presently investigating officers of the Kenya National Blood Transfusion Service (KNBTS) believed to be part of a cartel that has allegedly been siphoning blood donated by Kenyans and selling it in Somalia by creating an artificial blood shortage in the country (Muriuki, 2020).

Like many other NBTSs around the world, KNBTS lacks computerized technology and sustainable blood donation strategies to perform all its duties, one of which is to, monitor and evaluate the standards in respect of blood donation, processing, movement and distribution of blood for the purpose of efficient blood transfusion.

1.3 Aim

The project aims to develop an information system to support donation, processing, and distribution of blood as well as movement of blood by using a Quick Response (QR) -code based mobile application scanner and a backend web-based system implementing business intelligence predictive analysis.

1.4 Specific Objectives

i. To analyse current blood donation strategies
ii. To review blood bank information systems
iii. To design and develop an updated blood bank information system
iv. To test the developed system

1.5 Justification

Health CS Mutahi Kagwe highlighted that the Health Ministry is putting in place measures of ensuring the issue of blood shortage is dealt with once and for all. These include a Bill to govern donation, processing and distribution of blood as well as setting up of an ICT system to trace the movement of blood from the source to the final stage when its transfused to a patient (Muriuki, 2020). Therefore, showing the need for the developed system which will be able to track the movement of blood through QR code-based technology and come up with blood donation strategies.

1.6 Scope and Limitations

This project’s scope covers existing blood transfusion services in Kenya.

Lack of resources is a limitation that has caused the project to narrow down to use of QR codes instead of Radio Frequency Identification technology (RFID) to track the movement of blood.

Chapter 2: Literature Review

2.1 Introduction

This chapter aims to review blood donation and blood banks as a topic. It is a topic that has articles written on it as well as books. This chapter aims in reviewing the articles and books by analysing the current situation in which blood banks evaluate and monitor their blood donation process.

2.2 Current Practices

According to (Information et al., 2010) blood banks has several core components; A specific unit that is assigned by ministry of health to coordinate, manage, and monitor the blood system throughout the country, Advisory body that can assist ministry of health in formulating policy and plans, setting standards and advising on key issues, Blood transfusion services (BTS) involved in donor recruitment, blood and plasma collection, and the testing, processing, storage and distribution of blood and blood products, Hospital blood banks, clinical transfusion services and transfusion committees are responsible for the timely provision of compatible blood and its safe and appropriate use.

In many if not all developed countries, the National Blood Transfusion Service (NBTS) has an integrated blood and donor management system. Donor register is done on the organization's website or when the donor visits the blood collection center after which the donor is contacted either via Short Message Service (SMS) or email. There are also many other online blood banks, donor databases and blood donor mobile applications set up by organizations independent of the NBTS. These organizations ease the processes of recruitment and mobilization of donors whenever there are urgent blood appeals and keep donor blood donation records and test result details (Ireri, 2014).

Blood bank is a cache or bank for blood or blood components, gathered because of blood donation, stored, and preserved for later use through a blood transfusion. The term "blood bank" typically refers to a division of a hospital where the storage of blood product occurs and where proper testing is performed. However, it sometimes refers to a collection center, and indeed some hospitals also perform collection. In Kenya, the Kenya National Transfusion Center at the Kenyatta National Hospital (KNH) is responsible for processing blood and distributing it to blood banks located all over the republic. These blood banks then avail the blood for use by hospitals and health centers.

Kenya has six centralized blood banks throughout the country known as Regional Blood transfusion Centers (RBTC). All willing blood donors can walk to any of the RBTCs located in Nairobi, Embu, Nakuru, Mombasa, Kisumu or Eldoret. They can also choose to walk to any of the Provincial or District hospital-based blood banks and donate blood voluntarily. The reason for regional blood repositories is to ensure that dozens of neighboring local district hospitals are always stocked with an adequate amount of blood to meet the transfusion needs especially in the event of an emergency (Kiwanja, 2007).

KNBTS has intentions of eventually automating its processes and has recently started storing some data in excel format, but now most of its data is in paper form. In January 2013 KNBTS launched a project funded by the Centers for Disease Control (CDC) Foundation and supported by partners including the Blood Link Foundation, Intel iSOFT Consulting and mHealth Kenya. The main aim of this project being to come up with a solution to avert low donor turn outs and encourage donor participation during blood drives. The project involves the creation and setting up of the text4life system, a platform through which KNBTS aims to ease the process of donor mobilization by sending text message notifications to potential donors on dates and venues of future blood donation drives in their county. Using this system, a potential donor registers online on the KNBTS website by entering their phone number, email address and county of residence (Salah, 2014).

The process of blood donation at KNBTS is done by first registration where you need to complete a very simple registration form which contains all required contact information needed to begin the donation process. Screening will then follow where a drop of blood from your finger will be taken for a simple test to ensure that your blood iron levels are suitable for donating blood. After passing the screening test successfully, you will be directed to a donor bed for donation. This takes between 6-10 minutes only. Your blood is then tested for Human Immunodeficiency Virus (HIV), Hepatitis A & B among other infections. Finally, you can collect your results at the KNBTS center nearest to where you donated blood from (Kenya National Blood Transfusion Service, 2019)

KNBTS is responsible for the collection of blood to provide safe blood to Kenyan hospitals. Initially, it started off with an annual average of 10,000 units of blood whereby one unit of blood is equivalent to 450ml. This led to the formation of partnerships to collect more blood. Currently the KNBTS works in conjunction with Hope Worldwide which collects blood in the community and in faith based organizations, the Kenya Red Cross which is responsible for collection of blood in middle level 2 colleges and secondary schools and Bloodlink Foundation which is charged with the collection of blood from donors in universities and corporate institutions. These partnerships, as well as several national blood drives and media campaigns, have led to a significant increase in the amount of blood units collected nationally. Despite these efforts the national minimum target of 200,000 units of blood needed annually has never been reached (Njuguna, 2012).

A population-based, cross-sectional survey was conducted in 2007 among 15- to 64-year-olds. Consenting participants were interviewed about blood donation history and were tested for HIV, Herpes Simplex Virus (HSV)-2, and syphilis. The results were of the 17 940 people surveyed, 445 (2·3%) reported donating blood in the prior 12 months. Sixty-four per cent were voluntary donors, and the rest were Family Replacement Donors (FRD). Compared to FRD, most voluntary donors were < 25 years old (59% versus 18%), from the highest wealth quintile (57% versus 42%) and single (64% versus 23%). In addition, voluntary donors were less likely to have been sexually active than replacement donors (43% versus 13%). HIV prevalence was lower among voluntary donors than among FRD (2·6% versus 7·4%, P -value = 0·07). The survey concluded that majority of blood donors in Kenya are voluntary with lower potential risk of Transfusion Transmissible Infections (TTI) (Kimani et al., 2011).

Apart from collection and distribution of blood the KNBTS is also responsible for the coordination, management, monitoring and evaluation of the national blood transfusion programme, setting up blood transfusion and waste management standards to be followed by blood centers and health facilities, ensuring efficient procurement and supply chain systems for blood centers and the coordination of organizations involved in blood transfusion service provision among others.

2.2.1 Challenges Present in The Current Scenario

The supply of blood product depends totally on the donors themselves. It has been reported that the number of donors has fluctuated where the demand for blood product is irregular across the world (Beliën & Forcé, 2012). In developing countries, lack of resources, lack of professional management, myths and misconceptions arising from cultural and social differences form a barrier to blood donation (Rahman et al., 2011).

In present scenario searching for blood donors can take place through online blood bank websites or blood bank centers or by toll free numbers. So far it is a time taken process.

The lack of sustainable strategies to recruit and retain donors is one of the main challenges the KNBTS faces. The reasons why donors stop donating or do not return after they donate for the first time are diverse and may correlate with demographic factors like age (Kasraian, 2010). A report published by KNBTS March 2012 indicated that majority of the donor in Kenya are between 16 and 20 years of age that is 57.7% of all donors.

Interviews conducted at the KNBTS national office revealed that the institution has a manual Blood Bank Management System and that most of the processes including record keeping and inventory control are manual. Although each blood bank maintains its own records, there lacks a central location from which records from the various banks can be accessed. The blood donor's records are also not efficiently managed given that someone is given donors card which has no national level management of the records i.e. it's just a serial number which is not assigned meaning in the context of blood donation process.

Global Consultation Universal Access to Safe Blood Transfusion indicated the main challenges in achieving universal access to safe blood transfusion are organizational ones such as: fragmentation and low efficiency of blood services' operations, lack of tangible political commitment and support, and poor institutional coordination. Difficulties in ensuring the sustainability of blood services were elaborated upon. These could be due to inadequate financial resources or trained human resources, inadequate integration of blood transfusion services in health care systems and problems of geographically isolated communities of small populations. Blood shortages, low donation rates, high discard rates were impediments in making safe blood available to all patients in all situations in a timely manner. It was mentioned that considerable reliance on family/replacement and paid donations in many countries, high prevalence of transfusion transmissible infections in some regions and a shrinking base of safe voluntary blood donors also contributes to unsafe blood transfusions.

WHO, Americas region Dr José Ramiro Cruz, Regional Adviser, Laboratory and Blood Services, Pan American Health Organization (PAHO)/WHO- Association of Medical Reporting Organizations (AMRO) identified the lack of availability of reliable data from blood services, hospital-based services, and other blood banks as a major challenge. Absence of mechanisms to assess the efficiency of blood transfusion services and lack of understanding of the true need for blood and blood products were highlighted as the areas requiring attention. Dr Cruz mentioned that high discard rate of blood collected in the hospitals as compared to the blood services was an important consideration for discouraging blood collection in hospital blood banks. Lack of oversight and regulation of blood transfusion services, inadequate systems of data collection, reliance on family / replacement donors and transfusion of inadequately tested or untested blood were also noted as major issues.

Since blood centers in most countries typically rely on volunteer donors to meet the Hospitals' needs, donor retention is critical for blood banks. Identifying regular donors is critical for the advance planning of blood banks to guarantee a stable blood supply (Alkahtani & Jilani, 2019). Like many other NBTSs around the world, KNBTS lacks self-sufficiency and sustainable strategies to perform all its duties, one of which is to recruit and retain donors for the purpose of regular blood collection. Voluntary Non-Remunerated Blood Donors (VNRBD) are the main source of blood donations and their blood is considered the safest compared to that from family/replacement and paid donors(Kimani et al., 2011). One of the duties of a National Blood Transfusion Service (NBTS) is to recruit VNRBDs. To enable recruitment and retention of donors, awareness needs to be created on the importance of regular blood donation by those who are within the donation age limits, that is, 16 to 65 years of age and weigh more than 50Kgs. KNBTS faces several challenges one of which is inadequate funding and personnel (Ireri, 2014).

2.2.2 Problems facing Current Scenario

As a result of the lack of a central location from which records from the various banks can be accessed, a situation in Kenya is frequently encountered where some banks have more demand than they can satisfy while in other banks the blood overstays and is eventually declared unfit for transmission resulting in wastage of the valued commodity. Blood has a short shelf life of 35 days and its demand is always high, therefore its supply should always be constant. The short shelf life of blood and blood related products necessitates up to date synchronized records that can be accessed from a national level. The effects of these challenges manifest themselves in the pronounced shortage of blood in the country. There is also the undeniable possibility of having a blood bank lack sufficient volume of some blood groups leaving patients stranded and some lives have been lost this way (Nzoka & Ananda, 2014). Timely access to safe blood is part of the WHO"s global health agenda and global strategic priorities (World Health Organization, 2009). The lack of timely access to safe blood by patients and the big gap between demand and supply of blood are problems faced by many countries especially those in the developing world. Every 10 minutes, about seven Kenyans need blood and are at risk of dying if it is not available, according to the KNBTS. This means that every day, 1,008 people are asking for blood. Just three teaspoonfuls of blood are enough to save the life of a premature baby. Yet, the shortage in blood banks has made this a taxing need to satisfy (Alushula, 2020).

The lack of a central location of records also leads to the procedure of undergoing blood transfusion in Kenya as not an easy one since most patients must source for blood in the event the hospitals lack blood of their type. Most patients have been forced to source for blood from making frantic calls on social media and settling for family replacer donors, a condition that according to the United States (US) Department of Health, is unadvisable due to high number of infection cases.

Inadequate funding and personnel in KNBTS have rendered the institution unable to provide adequate public awareness and education to both donors and non-donors in the country hence contributing to unsafe and inadequate blood supply.

KNBTS lacks computerized technology and sustainable blood donation strategies to perform all its duties, one of which is to manage, monitor and evaluate the standards in respect of blood donation, processing, movement, and distribution of blood for the purpose of efficient blood transfusion. This has cause crime in the country where a case opened on March 2020 seeking to find out roles played out by KNBTS officers in creating an artificial blood shortage in the country by illegally selling what is meant to be supplied to Kenyan hospitals (Muriuki, 2020). Official figures from the Kenya National Blood Transfusion Service (KNBTS) reveal that blood amounting to 1,000 units, a whopping third of the total collected from January to March was thrown out because it expired before it was tested (Kabale, 2020).

2.3 Current Supporting Technologies

In a blood bank, automation benefits from a broad range of systems and apparatus, including automated manufacturing equipment, control systems, automated laboratory systems, computers including laboratory or manufacturing database system. And all of them are organized in a hierarchy of hardware, software, and network components (Validation Task Force of the International Society of Blood Transfusion Working Party on Information Technology, 2010).

Mobile technology is used in blood bank systems, for example, through; Android blood banking systems, SMS technology whereby it is essential to assess blood donation behavior from registered blood donors after receiving SMS reminders (Gombachika & Monawe, 2011), General Packet Radio Service (GPRS) and a centralized server to store blood donors and blood banks information, Unstructured Supplementary Service Data (USSD) technology as a layout that will help achieve a comprehensive location of blood units matching a patient's blood group (Mundama, 2013).

In the health industry, other than information processing efficiency, the barcode technology is prevalent for its intrinsic capability to categorize, track and manage the life-critical medical materials including blood products. The barcode technology is comprised of the machine-readable symbols used to encode information to automate a business process. Barcode enables the machine to acquire data via scanning and recognizing automatically, which can not only improve working efficiency but also avoid the errors due to manual entry (Li et al., 2007a).

RFID technology is superior to traditional barcode identification, i.e. it does not require line-of-sight, allows simultaneous read of multiple tags, is able to store more information on the chip, can include sensors for condition monitoring such as time and temperature, and enables automatic identification and data capture. Furthermore, it can be used in combination with barcode technology, to increase reliability (Katsiri et al., 2016). RFID technology will be used for blood product manipulation from the very beginning of the blood taking process at the donor when the whole blood and its components are taken into special blood bags. The blood bags must be assembled before the blood taking according to the type of taking. A large amount of information must be written down before the taking, such as the charge number of blood bags, and other labels according the taking type. The natural taking is identified by bar code with the taking number; nurse ID, taking (capitation) device with its technological parameters (time, weight, and temperature). Then the information is passed into the information system and to the production (Kebo et al., 2010).

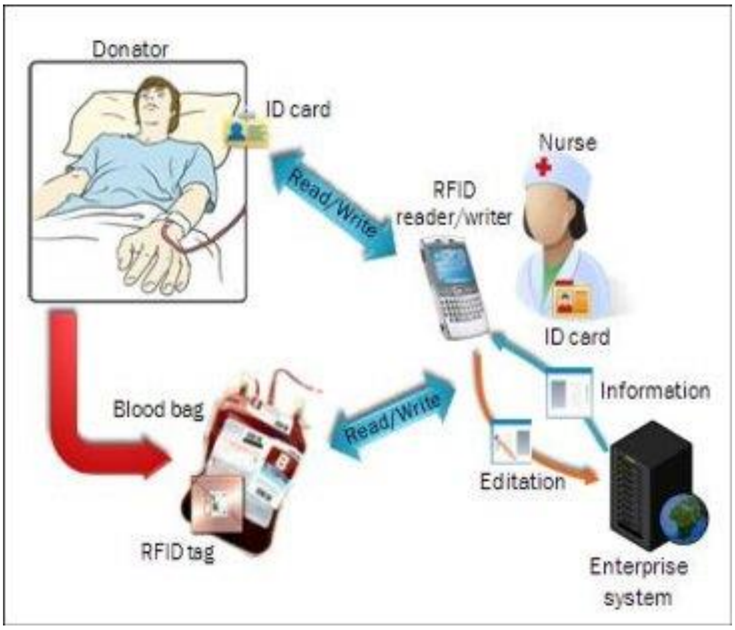

Figure 2.1: The use of RFID technology at the place of blood taking

(Kebo et al., 2010)

All the information regarding the processing and laboratory tests are continuously recorded and eventually automatically stored into information system. Consequently, it is necessary to mark the blood bag by label with all important information including the bar code. In the case of negative results of all the laboratory tests, the transfusion products can be released to the expediting group – or conversely it must be liquidated. The RFID technology application enables the information storage into the tag in the blood bag directly, without necessity of bag label changing. This method ensures the monitoring and control from the donor reception up to expedition or liquidation of the products. The blood products are, after the release, inserted into special thermo-boxes – containers, warmed or cooled to the temperature satisfying the limits for blood product storage and then passed to the expediting group for the entering in a repository.

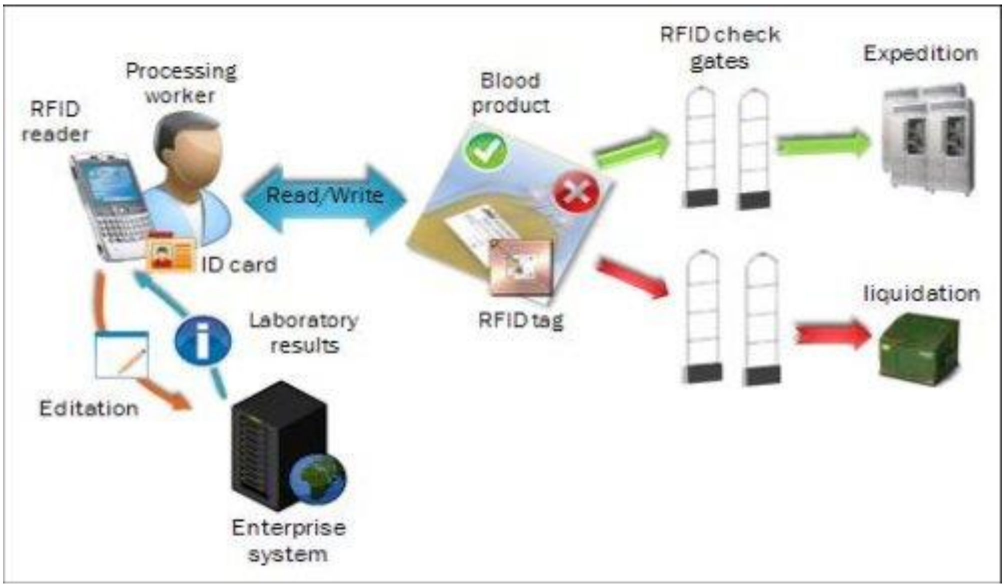

Figure 2.2: RFID technology at the processing of blood products

(Kebo et al., 2010)

While the benefits of RFID implementation in transfusion service are numerous, there are barriers that hinder adoption as denoted in. Cost of RFID tags can be 10-15 times more expensive than barcode systems. Additional costs involved with RFID system implementation include readers, middleware, and software applications. RFID readers can cost between 5320.26 to 319215.90 Kenyan Shilling each. Software applications can range in cost from Ksh.2660132.50to over Ksh.10640530 for facility-wide implementation (Coustasse et al., 2015).

2.3.1 Technologies Used to Campaign and Raise Awareness About Blood Donation

Internet penetration rate is at an all-time high with 20% of Africa’s population able to access the internet. This implies that more people would be able to access the KNBTS website today and register online if they are unable to visit the KNBTS regional offices and register (ITU Report, 2014). Due to the increase in the use of the internet, there has also been an increase in access to tools that can be used to create awareness on blood donation such as social media.

In Kenya, awareness, mobilization and recruitment mainly through mobile blood drives is done by Non-Governmental Organizations such as the Kenya Red Cross and Hope Worldwide Kenya, and private associations like Community Blood Donor clubs and Pledge 25 which promotes voluntary blood donation among the youth, their mission being to increase the blood supplied by KNBTS (Ireri, 2014).

To boost collections by encouraging repeat donations, the Kenya National Blood Transfusion Service is exploring the likelihood of reaching previous donors through targeted print, radio, and television advertising. According to analyzed data from a national Acquired Immune Deficiency Syndrome (AIDS) Indicator Survey which was done to determine whether previous donors have significant exposure to media, respondents reporting history of blood donation had significantly higher exposure to print, radio, and television media than those without history of blood donation. Targeted media campaigns encouraging repeat donation are likely to reach previous donors even in resource-limited settings (Basavaraju et al., 2010).

2.3.2 Blood Typing and Crossmatching

There are four types of blood groups. O, A, B, and AB. Blood typing test is used to find out the blood group. The presence of certain type of antigens on the red blood cells determines the patient’s blood type. Antigens themselves are specific proteins that cause the production of antibodies by the individual’s immune system. The process of cross-matching detects major and minor antigens. The ABO is the most important blood group because of the production of antibodies in patients who do not have the right antigens. Wrong red cells by the donor are identified as a foreign body and result in severe transfusion hemolytic reaction (Butch & Oberman, 1997).

Blood cross-matching is very essential in any major surgery. Essentially, it is a test that is performed prior to transfusing blood to determine if the donor’s blood is compatible with the recipient’s blood. The process approximately takes one hour, and it should be performed at least three days prior to transfusion so that it is ready to be transfused for the surgical patient if required. Strict guidelines should be followed where blood is to be collected, delivered to the lab, and thorough and precise tests should be carried out to produce necessary blood for the recipient patient The blood is mixed in the lab with some commercially available antibodies against blood types. If the blood cells stick together to each other, meaning that they agglutinate, it means that the blood has reacted with one or more of the antibodies. Serious adverse effects of blood transfusion do occur sometimes because of human error, despite scientific and technical advances in blood group immunology to make the transfusion of blood a safe procedure (Nasr & Yaqoob, 2016).

Blood type results are confirmed by mixing anti serum with the blood. If the blood cells agglutinate when mixed with anti-A serum, the blood type is A. If the cells agglutinate when mixed with anti-B serum, the blood type is B. If the blood cells agglutinate when mixed with both serums, then the blood type is AB. Lastly, if the blood does not agglutinate when either serum is added, then the blood type is O. Individuals with blood type O have anti A and anti B antibodies. Individuals with blood type B have anti-A antibodies and individuals with blood type A have anti-B antibodies. An, whereas individual has type A blood, if the blood clumps when only B cells are added. Individuals will have type B blood, if the blood clumps when only the A cells are added. If the blood clumps in both cases, then individual has type O blood and if the individual's blood does not clump when both types of bloods are added, then he has blood type AB (L I Boral, 1977).

2.3.3 How blood is collected, marked, stored, and utilized

According to (American Red Cross, 2020), for a whole blood donation, about one pint of blood is collected; several small test tubes of blood are also collected for testing. The donation, test tubes and the donor record are labelled with an identical bar code label. The donated blood is then kept on ice before being taken to a Red Cross centre for processing; the test tubes go to the lab. The blood is put on ice immediately so that the metabolic activity of its cells is reduced, and they will consume less oxygen. Some data suggests that if analysis of a sample is delayed for even ten minutes at room temperature, PaO2 values will be significantly lowered due to continued consumption of oxygen by the leukocytes and platelets in the sample (Zalkin, 2015). At the processing center, information about the donation is scanned into a computer database. Most whole blood donations are spun in centrifuges to separate it into transfusable components: red cells, platelets, and plasma. Each component is packaged as a unit which is a standardized amount that doctors will use when transfusing a patient. The test tubes arrive at a testing laboratory where test results are transferred electronically to the processing center within 24 hours. If a test result is positive, the donation will be discarded, and the donor will be. When test results are received, units suitable for transfusion are labeled and stored. Red cells are stored in refrigerators at 6ºC for up to 42 days. Platelets are stored at room temperature in agitators for up to five days. Plasma and cryo are frozen and stored in freezers for up to one year. Blood is then available to be shipped to hospitals 24 hours a day, 7 days a week. Hospitals typically keep some blood units on their shelves, but may call for more at any time, such as in case of large-scale emergencies.

2.3.4 How patients are served

According to the National Blood Transfusion Service of Kenya (2001), before any transfusion of blood or a blood product, a written request signed by a doctor or issued under his responsibility must be made which specifies the identity of the recipient , the clinical indication, and the nature and quantity of the blood or products to be administered. It is the service provider's responsibility to inform the recipient of the blood transfusion process, that the success of the process cannot be guaranteed, and that there is slight possibility of inadvertent risk, either reactive or ineffective, from blood transfusion. Transfusion of blood or any product must be based on a careful assessment by the clinician to determine the necessity for such transfusion. There shall be no age limit for a person who needs blood transfusion. The judgment that blood transfusion is required by recipient will be made by the attending clinician. As much as possible the patient should receive only the needed component of blood. The actual transfusion must be given under the responsibility of a doctor. Patients receiving blood transfusion must be under continuous observation for the first 15 minutes, and thereafter they must be observed at half hour intervals until the unit being transferred has ended and finally at 24 hours after the last transfusion. Any observation of abnormal signs or symptoms should lead to immediate stoppage of the transfusion. The doctor in charge of the patient and the officer in charge of the blood bank shall be informed immediately for necessary intervention and investigation. Immediate or delayed transfusion reactions must be reported to the laboratory providing the blood. Pulse rate, blood pressure, temperature and respiratory rate must be recorded before, during, and after transfusion according to the transmission monitoring chat. The beginning and end of each transfusion must be recorded in the chat. The transfusion monitoring chart should be carefully kept in the patient’s case file.

2.4 Related Works

I. **Sistema Integrado de Bancos de Sangue - SIBAS (China)**

In 1999, to further improve its service performance and quality, the Macau Blood Transfusion Center CTS-Macau, cooperated with Institute of Systems and Computer Engineering of Macau (INESC-Macau), initiated the computerized and networked blood bank information system—Sistema Integra do de Bancos de Sangue (SIBAS). It owns full-function Intranet/Internet network system, adopts all-round autonomous blood testing and producing apparatus, utilizes the barcode-based blood tracking and managing paradigm, and has fully realized the computerized and networked blood bank information system whose practical infrastructure is as shown in figure 2.1. The computers scatter in every division of the blood bank such as reception, collection area, laboratories, stocks, and even blood mobiles. Most of them connect to blood bank databases through Intranet network to share and interchange blood bank information. The system has two servers where the first one is to implement one-to-one service strategy, namely, a serve (maybe as virtual machine) is specially designed and optimized for the specific service such as data management (independent database for donor, donation, laboratory, stock, staff and materials), document management (printing, scanning, and faxing), Virtual Private Network (VPN) to hospitals and health bureau, and Internet information accessing. Secondly, there is a server for synchronous database backup and a magnetic tape server for daily database backup (Li et al., 2007b).

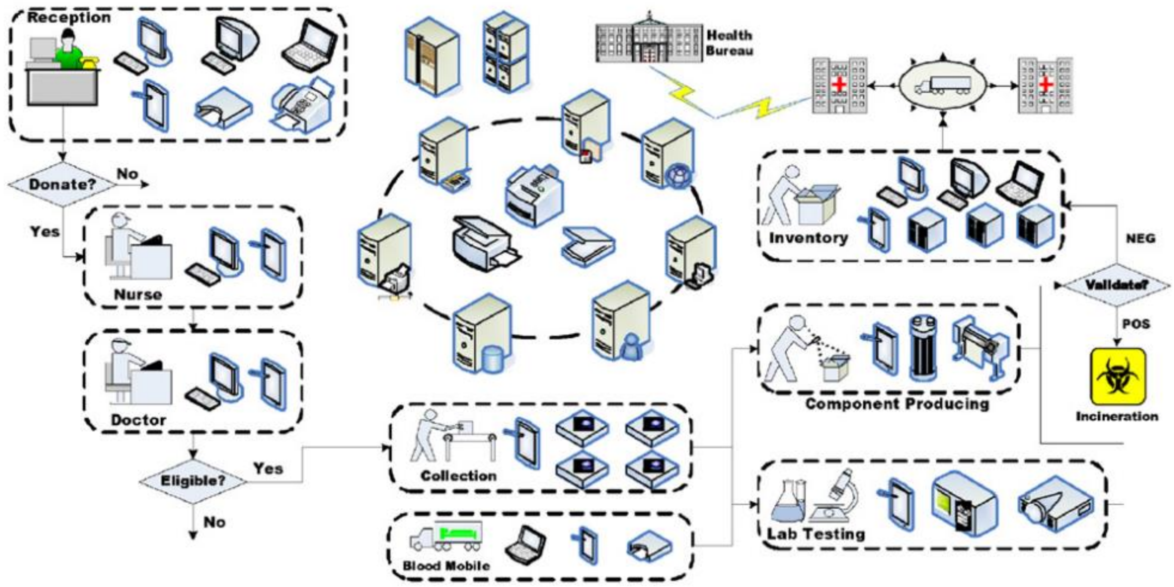

Figure 2.3: SIBAS System Work Flow

(Li et al., 2007b)

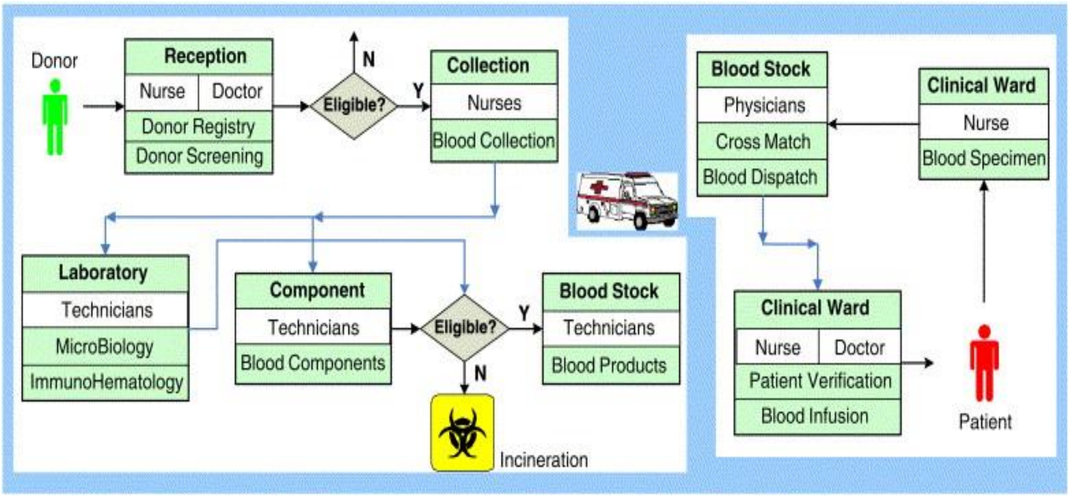

Figure 2.4: SIBAS System Architecture

(Li et al., 2007b)

II. Smart Blood Bank Information System – RedSplash Application (Kenya)

Students came together on February 2019 and formed a community-based organization called RedSplash with an aim of holding blood donation drives to save lives of people who need blood during critical conditions like road accidents. With the dynamic age of technology, the team that consists of students aged 18-25 came up with a Mobile Android Application named RedSplash. Once you register and log in to the application, you get a notification on the latest medical appeals for blood donation. A user can enter the type and amount of blood needed by the patient, the hospital they are in is also highlighted and their phone number too. Also, a share button is placed in each appeal to enable the message to be disbursed to various social media platforms. The app also shows a due donor and it also rates if the donor is willing to donate blood (this applies to a regular donor). The application also has a blog that talks on health and fitness topics while creating the importance of donating blood. A donor also gets thank you notes through an SMS once their blood has been used to save a life. The application also reminds the regular donors to donate blood sometimes later after the previous donation (Mutheu, 2019). The organization exists to avail safe and free blood to patients who require transfusion treatment in a timely manner without any discrimination.

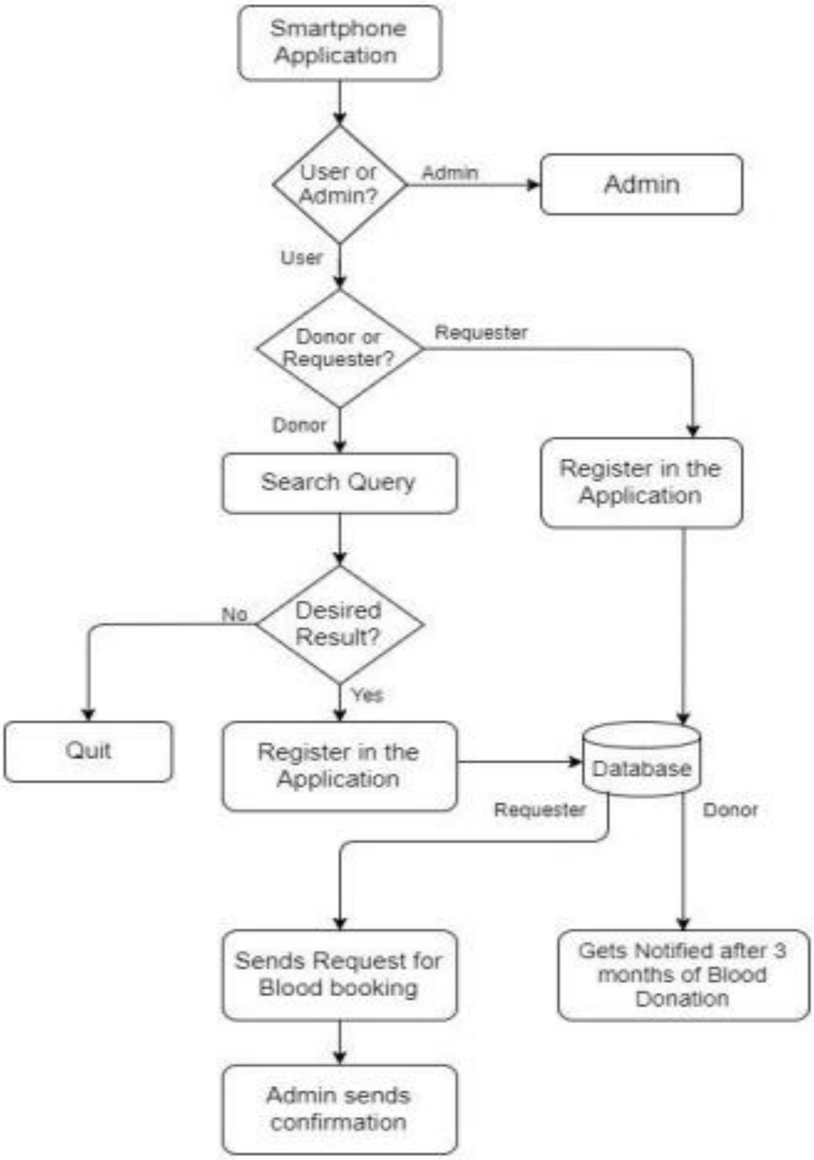

Figure 2.5: Workflow of RedSplash App

(Shinde et al., 2018)

III. Smart phone based Virtual Blood Bank in India

This system uses GPRS and a centralized server to store blood donors and blood banks information. People who seek blood also communicate with the server through their mobile devices, specifying their blood type and current location in a subscriber application. The server matches the blood type and location with the profiles of registered donors or blood banks, retrieves the information and sends it to the seeker via GPRS (Rahman et al., 2011).

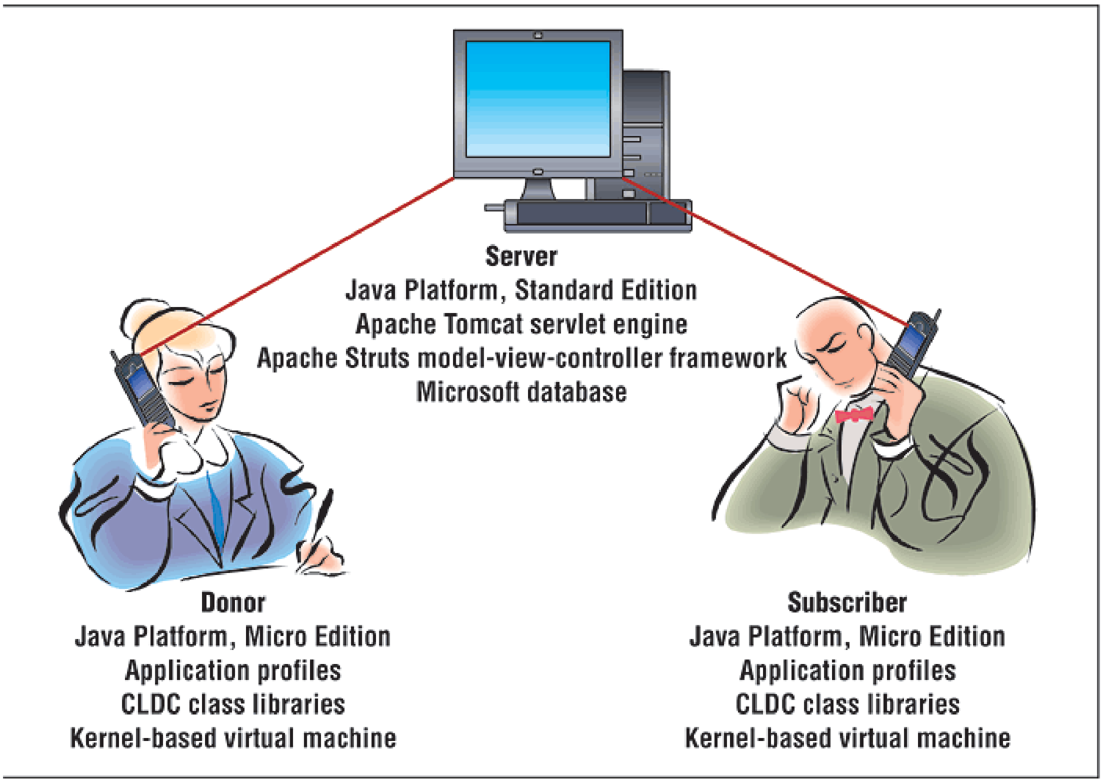

Figure 2.6: Virtual Blood bank

(Singh et al., 2007)

IV. Blood Bank Information System (BBIS) Based on Cloud Computing in Indonesia

This is a new concept of Blood Bank Information System using Cloud Computing for a Rural Area that provides the facility to provide blood at any time and any situation to a seeker. Apart from that seeker is also able to call the donor in emergency. This Blood Bank Information System connects hospitals, Unit Transfusi Darah Palang Merah Indonesia (UTD PMI) which is a RBTS in Indonesia, and personal donor within one web-based and mobile application. Web service, database service, and transaction-based service are the ideal applications for cloud computing. It also can be easy to use whether using personal computer or portable devices. This application offers simplicity for hospitals on accessing and requesting blood supply to UTD PMI or directly to personal donor. It also equipped with other supporting functions (Sahid Ramadhan et al., 2019).

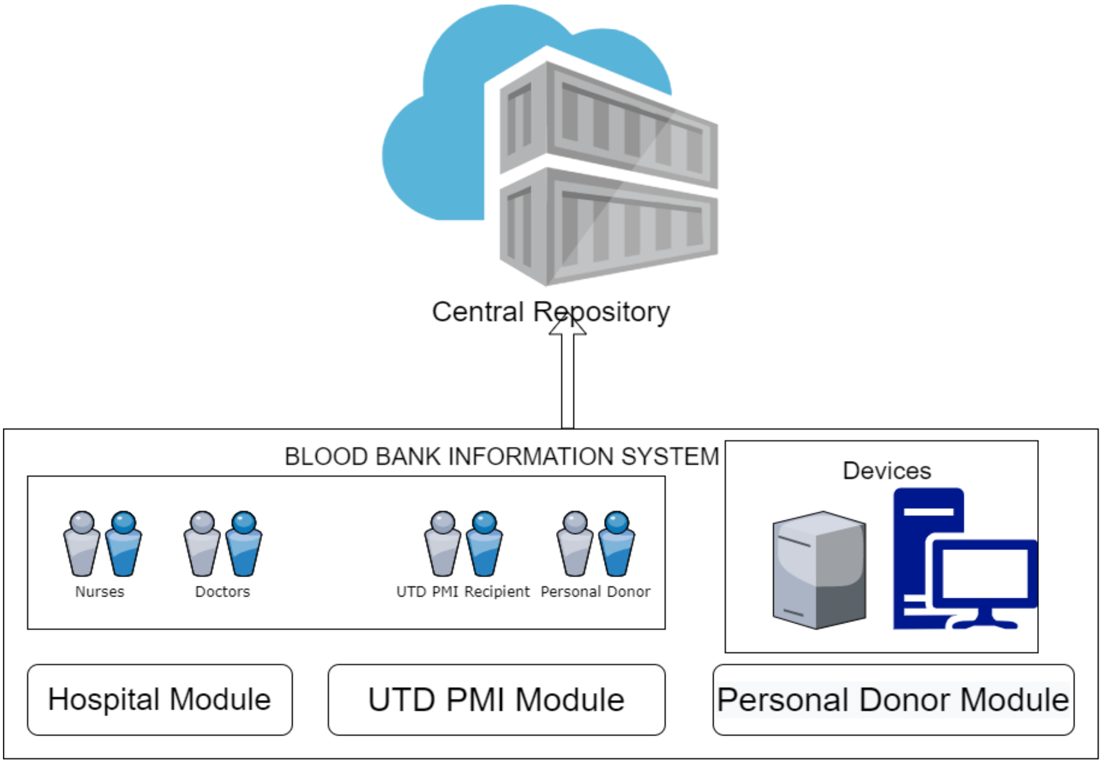

Figure 2.7: BBIS Cloud Computing System Architecture in Indonesia

2.5 Gaps in the existing systems

Existing blood bank information systems that use barcodes are limited, for example, SIBAS. Knels et al., (2010) reported that to scan one barcode, it takes 1 to 2 seconds, which is considered inefficient. This is one of the reasons that 2-D barcode and RFID technology have been suggested to replace the current linear barcode.

The cloud computing BBIS in Indonesia is at a disadvantage since it just maintains Blood Bank data and does not focus on donor reactions while donating blood. The Virtual Blood bank in India that uses GPRS has limitations, i.e. anonymity of donor information is not maintained which is a vital issue in donor recruitment system urged by WHO.

SMS-based blood bank services such as the one launched by Indian Medical Association (IMA) still lacks in maintenance of confidentiality and development of donor motivational program and donor counseling which is vital for collecting voluntary non-remunerated blood donation.

The RedSplash android application that was launched in Kenya lacks a way of tracing blood movement. Moreover, it is an android application and therefore limits use to only android device owners. The application lacks role-based security such that it allows a donor to view a patient's contact details which is a view that should only be restricted to the administrator only for security purposes. Therefore, the administrator should be the one to contact the donor and request for their blood.

In Kenya, the current system in use by the blood banks and most of the government hospitals is a manual system. To mobilize donors to donate blood, hospitals usually organize blood donation camps at random places and the whole process is done manually. The system used does not allow for participation from people at different geographical locations. KNBTS and other blood centers around the country currently lack a computerized Blood bank information system and database of blood donors. Its manual systems are not effective and lack the capability to handle issues that prevent donors from donating blood.

The existing systems give limited attention to accessibility, user friendliness and anonymity of information. This project has developed a system which is not only accessible to all users who have access to the internet and keeps anonymity of donor's information but also maintains the checklists provided by WHO for safe blood management.

2.6 Solutions

Based on reviewed literature and the study on the perception of blood donation, lack of awareness and lack of donor education are the main reasons why people do not or stop donating blood. Communication from blood donation service to the donors should be enhanced and therefore the most suitable solution is an ICT based blood donor information needs driven system. With increase in use of mobile technology a solution that utilizes this technology would increase the number of recruited donors and help retain them. The use of a computerized Database Management System (DBMS) such as MySQL which this project has used would also help KNBTS reduce the number of blood units discarded due to expiry and reduce, if not stop, wastage of collected blood.

A well-designed computerized blood bank information system that this project has implemented would ensure that there is a constant supply of blood in the blood banks through regular collection from repeat donors and proper monitoring of the expired blood group, as any blood unit will expire in 35 days. Therefore, the system ensures proper record keeping of the blood bags which prevents the transfusion of expired blood groups to patient. This function also shows how many units is left of the blood stock in a particular blood bank so that the stockiest gives that unit first to the patient or hospital in need of blood hence the system follows the First In Fist Out concept (FIFO). This prevents having too much blood in stock at the moment when it is not needed.

In addition, this project has used QR technology which will go hand in hand with mobile technology, and predictive analytics to meet the blood donation strategies.

2.6.1 QR Technology

QR code is a machine-readable optical label with information on the associated item or product. In barcodes, information is coded in one direction or one dimension only. On the other hand, QR is a 2-D barcode and can therefore store more information. It can be read easily and can be used at no cost and without worrying about patent problems. They are becoming a public code used worldwide (Chang, 2014).

Inventory control plays a vital role in the blood bank information system because this function provides the precise information such as how much unit of the blood group is available and which blood group is going to finish. Inventory includes the donor inventory and the seeker inventory (Kulshreshtha & Maheshwari, 2016).

Therefore, this project developed a system that generates QR codes that store donor and blood unit information. The codes are scanned via a mobile android application scanner and the information stored in the database. The QR code that has blood donor and unit information is attached to its respective blood bag. The blood bag whenever it undergoes any movement, the database will store all its movement information. Through this, the BBIS is able to track blood movement from donation to the moment its transfused into a patient. Once transfused, a notification is automatically sent to the respective blood donor.

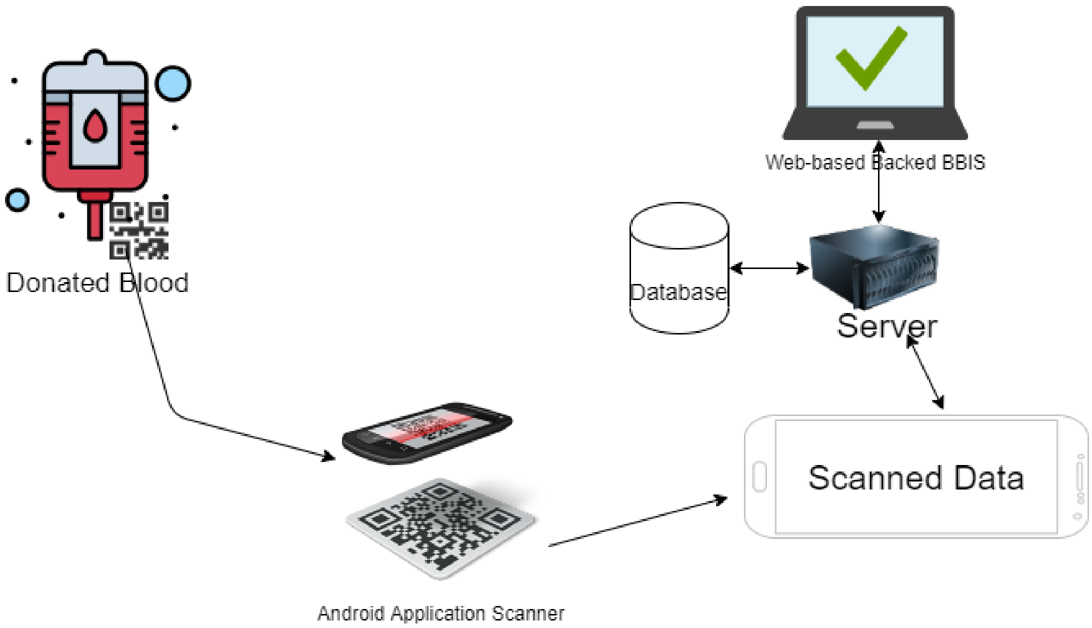

Figure 2.8: QR - code concept in developed system

2.6.2 Predictive Analytics

It involves the use of Predictive analytics which is a set of business intelligence (BI) technologies that uncovers relationships and patterns within large volumes of data that can be used to predict behavior and events. Unlike other BI technologies, predictive analytics is forward-looking, using past events to anticipate the future (Boonsiritomachai et al., 2016).

The system used predictive analytics to predict when blood is going to be needed, find a way to collect as much blood as possible and see to it that it is consumed in the shortest time. It has also been used to collect blood from an area that has been pinpointed by a user, i.e. request blood from the nearest hospital or donor. The searching technique will be improvised by giving the results area-wise and blood group-wise.

2.7 Conceptual framework

This is a conceptual diagram that shows how the developed system functions. The user logs into the web- based system and tries to authenticate their information. If the log in credentials are not approved the administrator will have to re-enter their credentials. If the credentials are accepted, their respective page will open.

Administrators from a respective blood bank can generate QR codes needed to track the blood bags. There is a mobile android application where the QR code can be scanned at every point of movement of each blood bag. The app is integrated by the system's database therefore storing the blood bags inventory information. The mobile application can also automatically send a donor the notification once their blood donation has been transfused to a patient.

The donor page is only for already registered users. If a donor wishes to respond to a requested blood appeal by the admin from a user, their information will be stored and used to generate a QR code. The system is developed to allow blood appeals from hospitals and patients and then pinpoint location and request blood from hospitals or donors nearby.

Existing blood banks in Kenya are also users of the system. Patients can know about the nearby blood banks depending on their location. The blood banks regularly update their blood stocks and share that information on their module (Jog et al., 2017). If blood stays past a certain duration an alert to the relevant authorities is sent.

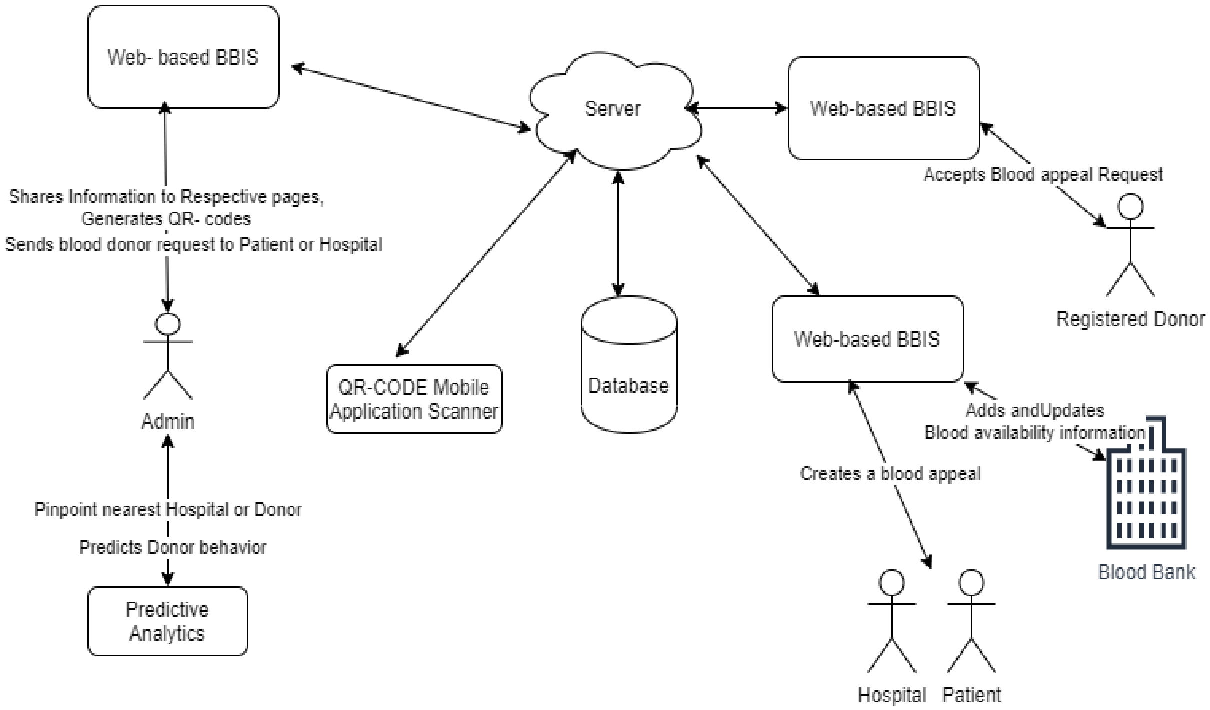

Figure 2.9: Conceptual Diagram

Chapter 3: Research Methodology

3.1 Introduction

Methodology based on Institute of Electrical and Electronics Engineers (IEEE) (Land et al., 2012) is a systematic approach to conducting at least one complete phase, for example, design; testing of software production, consisting of a set of guidelines, activities, techniques and tools, based on a particular philosophy of system development and the target system. (Avison & Fitzgerald, 1995) defines Systems development methodology as a collection of procedures, techniques, tools, and documentation aids which help the systems developers in their effort to implement a new information system.

This project applied the Prototype Methodology since the approach can be used for development of a user interface of different applications independently of the type – desktop, web-based, mobile. The user interface is crucial in the development of software applications. If it is well designed it could help users to achieve their goals, to satisfy them and to encourage them to use the system. Software prototypes support development teams to explore usability, usefulness, and acceptability of their projects.

3.2 Prototype Methodology

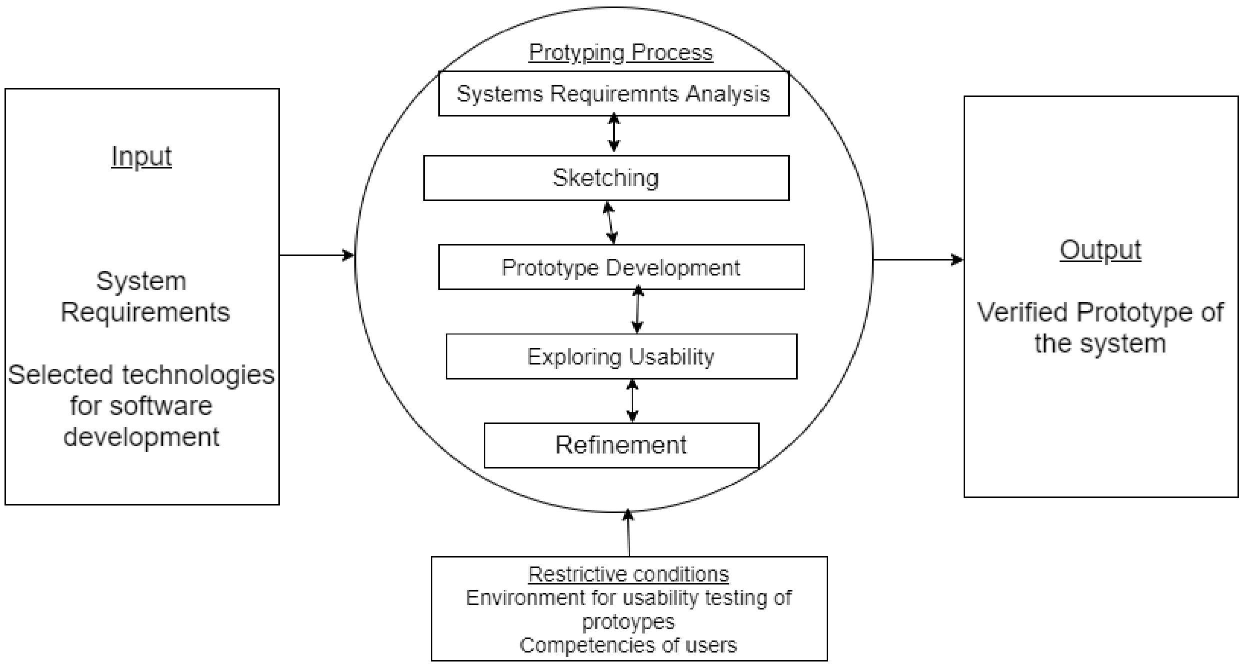

Figure 3.1: Prototype Model

A prototype is an artifact that approximates a feature (or multiple features) of a product, service, or system (Otto and Wood, 2001). The methodology includes activities that can anticipate possible changes before significant rework is required. For example, a prototype system may be developed to show some key features of the system to customers.

Input process parameters are the system requirements and the chosen technologies and tools for software development. They provide the necessary basis to perform the process. As an output artifact of the prototyping process is created a verified prototype that is in the development process should be further improved with a view that the applied approach is based on evolutionary prototyping. The restrictive conditions for conducting the process are associated with the Exploring Usability stage. These are the competencies of users who will participate in the prototyping process and the environment where it will be conducted (Nacheva, 2017).

3.2.1 System Requirements Analysis

This stage corresponds with the first statement of objectives mentioned by this project (chapter 1), i.e. to analyze current blood donation strategies. Its purpose is to undertake an assessment of the main interaction scenarios with the system from the user's perspective which requires modelling the main navigation flows.

3.2.2 Sketching.

This stage resembles planning and uses design diagrams as the basis for implementation of prototyping process. Reviewing of current systems is done in this stage hence corresponding with the second objective stated by this project (in chapter 1).

3.2.3 Prototype development

In terms of applying evolutionary approach to this prototyping model, it is necessary to apply tools that will be used in the development of the final system. The prototype forms its basis. Practically, this step is related to implementation of problem-solving plan. The system is designed and developed and designed hence corresponding with the third specific objectives stated by this project.

3.2.4 Exploring Usability

This stage corresponds with the final objective stated by this project, i.e. to test the developed system. The aim of this stage is to check the usability and usefulness of the prototype. This stage can be defined as the stage of checking the compatibility of established design concept, system requirements and user expectations. Application of methods and tools for usability testing and evaluation ought to be done in this step.

3.2.5 Refinement

The results from exploring usability stage serve as basis for making certain changes to the Refinement stage of the prototyping process. The aim of this stage is to modify the prototype in accordance with the results of the previous stage, to meet the mental models of representatives of the target audience, while complying with the system requirements.

Note: The stages in the prototyping process respectively correspond with each statement of objectives stated by this project. The prototyping process combines methods and approaches from different scientific fields. The process is repeated if it is necessary and needed hence, iterative.

3.3 Design Diagrams that will be drawn in Chapter 4

3.3.1 Context diagram

A context diagram is used to establish the context and boundaries of the system to be modelled. It includes which things are inside and outside of the system being modelled, and what is the relationship of the system with these external entities. It is also sometimes referred to as a level 0 data-flow diagram. The context diagram is drawn in order to define and clarify the boundaries of the software system. It identifies the flows of information between the system and external entities. The entire software system is shown as a single process (Hughes, 2016).

3.3.2 Level 1 & Level 2 Data Flow Diagrams (DFD)

A DFD is defined as a diagraph together with a binary relation, called the precedence relation. The nodes of the digraph represent the processes, data stores, and external entities, and the directed edges represent the data flows. The precedence relation for a DFD is an abstraction of the functional semantics and specifies the "is-used-to-produce" relationships among the data flows. Based on this definition, the notion of consistency in process decomposition is defined. The child DFD that results from decomposition is consistent with the parent process if the child DFD preserves the precedence relation for the parent process and does not introduce additional precedence relationships between the input and output flows of the parent process (Tao & Kung, 1991).

3.3.3 Entity relationship diagram (ERD)

It contains an Entity which has an Entity class (entity set) that is a structural description of things that share common attributes. An Entity instance is the occurrence of an entity. The diagram also includes an Attribute which describes an entity class. All entity instances of a given entity class have the same attributes but vary in the values of those attributes. Identifiers identifies an entity instance. Relationship describes how entities are related (Hingorani et al., 2017).

3.3.4 Database schema

A database schema denotes the description of this structure and behavior of a database. In an object relational database model such as a group such as proposed in SQL- 99, a database schema consist of the following elements; types tables and views, subtype In September relationships coma constraints and assertions, functions, stored procedures, and triggers and roles and privileges (Türker, 2001).

3.3.5 Graphical User Interface (GUI) designs

It is a type of user interface that allows users to interact with electronic devices through graphical icons and visual indicators such as secondary notation, instead of text-based user interfaces, typed command labels or text navigation (Galitz, 2007).

3.4 System Development Tools and Techniques

3.4.1 Computer language(s)

The project developed used PHP and Hyper Text Markup language 5 (HTML5) scripting languages which can collaborate with the SSAD approach that the system developed applied. The PHP tool is used to enable the system to make dynamic and interactive Web pages. The system was developed specifically using Laravel, an open – source PHP web framework. The Laravel framework has an expressive, elegant syntax and an already laid foundation that frees a user to create without sweating the small things hence making work easier for a developer. PHP supports many databases such as, MySQL which the system used as its DBMS. It is also an open source software that is free to download and use hence making it easy and affordable to use.

The official language for Android development is Java that was used to develop the mobile-based application. Large parts of Android are written in Java and its APIs are designed to be called primarily from Java.

3.4.2 Integrated Development Environment (IDE(s))

Visual Studio Code which is a source code editor is used by the developed system to add its own features to the editor.

Android Studio is the official IDE for Android application development. The project used the platform to develop the QR code scanner mobile application for the blood bank information system.

3.4.3 DBMS

The data is stored through MySQL DBMS because it is a user-friendly GUI that contains clients such as PHPMyAdmin. The project developed uses PHPMyAdmin because it provides a web interface as well as features such as importing and exporting of data and it can administer multiple servers.

3.5 Method used to test the developed system

This project tests the developed system using the functional testing method. This is because Functional testing covers how well the system executes the functions it is supposed to execute, including user commands, data manipulation, searches and business processes, user screens, and integrations. Functional testing covers the obvious surface type of functions, as well as the back-end operations (such as security and how upgrades affect the system).

3.6 Domain of Execution

The solution is executed through both mobile and web based. The project developed uses a mobile application to scan the QR generated codes. The mobile system is connected to the web server via a PHP page hence connecting the two domains. The system has a back-end web application because it allows any user to access the system through any device that has access to the internet and a web browser. This means, a user does not necessarily have to have a Personal Computer (PC) to access the application. Users can easily access the system from their phones which have internet access.

3.7 Modules and System Architecture

3.7.1 User Roles Management and Authentication

The module helps in role management by managing authorization which enables specifying the resources that users in the developed system are allowed access to. The module verifies that the user is who they claim to be by checking the provided username and password against what is stored in the database.

3.7.2 Administrator Module

This is a member of staff that has right to access the databases and manipulate the data. He or she has full privilege on the system's functions. The admin page will display all analytics and generate reports. For example, a display of availability of the different blood groups.

3.7.3 Blood Donor Module

The donor module is only for potential donors already subscribed to one of the national blood bank branches. He or she has offered to be notified in case of an emergency to donate blood.

3.7.4 Patient Module

The developed system seeks to provide patients with important information about the availability of their required blood type and the blood center in which it is available. In case of an unavailable type, the system will contact the nearest registered donors with the same blood type as requested.

3.7.5 Blood Bank Module

This module allows different blood banks in Kenya to enter details concerning blood availability in their centres and to also request for blood from other different blood banks or registered blood donors.

Chapter 4: System Analysis and Design

4.1 Introduction

This chapter expounds on how the system was developed to operate and how useful it will be to the user through the design diagrams which are illustrated. It also aims to specify the fact-finding techniques that the project applied for requirements discovery.

4.2 Requirements Gathering

4.2.1 Reviewing existing CBIS documentations

Documentation review is also another way I used to collect data by reviewing those existing CBIS'. I used document review for evaluation to gather background information. Reviewing existing documents helps you understand the history, philosophy, and operation of the program you are evaluating and the organization in which it operates.

The data gathering technique also helps when you need information to help you develop other data collection tools for evaluation. This is because reviewing existing documents helps to better understand the program and organization you are evaluating hence helping you formulate questions for questionnaires (Melbourne, 2017).

4.2.2 Questionnaires

Questionnaires are a useful fact-finding technique to collect information from a large number of users. Users fill up the questions which are given by the system analyst and then give the answers back to the system analyst. To fulfil the requirements of the project's system objectives, the questionnaires clearly define the questions to suit the objectives (Mamoun, 2015). This technique is useful for this project due to the COVID-19 Pandemic that took place during the period of the project's development. Questionnaires were presented to a sample of the target population and the results were analyzed to understand the user's requirements in relation to the use of a blood bank information system in the case of emergencies.

4.3 Analysis

Before designing a system there must be a thorough understanding of the old system and determine how computers can best be used to make its operation more effective. System analysis, then, is the process of gathering and interpreting facts, diagnosing problems, and using the information to recommend improvements to the system. A key question is, what is the source of the problem?

Analysis is a detailed study of the various operations performed by a system and their relationships within and outside of the system. A key question is, what must be done to solve the problem?

This project proposes to apply a Structured Systems Analysis and Design (SSAD). This is because theoretically the approach allows one to plan, manage and control a project well. These points are essential to deliver the product on time. Structured Analysis is a set of techniques and graphical tools. They allow the analyst to develop a new kind of system specifications that are easily understandable to the user. SSAD separates the logical and the physical systems design. Therefore, the system does not have to be implemented again with new hardware or software. (Gabry, 2017).

4.3.1 Functional Requirements

Functional requirements serve as the basis for the system to be built. They are requirements given in terms of required operations and/or data. The blood bank information system's functional requirements are as listed:

i. The system should be able to capture and store donors', blood banks', and blood bank inventory details into the My Structured Query Language (MYSQL) database.
ii. The system should be able to alert relevant authorities when there is a surge, i.e. having too much blood in stock at a particular blood bank hence preventing crime such as illegal blood trade.
iii. The system should be able to trail at what place and time a QR code was scanned to enhance security.
iv. The system should be able to connect the android application to MYSQL database via Hypertext Preprocessor (PHP) page.
v. The system should be able to generate pre-defined reports such as the list of donors, recipients, and blood quantity in the bank.
vi. The system should be able to allow administrators to delete, add and update data, blood bank inventory as predetermined by the transfusion centre procedures (Mundama, 2013).
vii. The system should be able to allow the super admin, blood donor, patient, and blood bank to login upon registration.

viii. The system should be able to allow the blood donor and blood bank to view blood request alerts.

ix. The system should be able to allow the blood donor to view his/her donation history.

x. The system should be able to allow the blood bank and patient to view his/her profile.

xi. The system should be able to allow the admin in a blood bank and patient to make a blood appeal.

xii. The system should allow the super admin to view blood alert responses.

xiii. The system should allow the blood bank, patient, super admin, and donor to edit his/her profile.

4.3.2 Non-Functional Requirements

(Glinz, 2005) defines non-functional requirements as those which specify how well the system performs its functions i.e. performance requirements and quality requirements.

I. Reliability

The system should be reliable in that when an individual wants to access information from the system, it should be available to the users.

II. Capacity

The storage capacity of the system should be big enough to store all the information needed for a large group for a long period of time that will enable the system to run faster.

III. Role-based security

The system should restrict users to a view based on user profile attributes. This access should be adjustable throughout the blood donation process cycle.

IV. Reusability

The System’s Database code should be reusable and exported into a library.

4.4 System Architecture

The system architecture of the developed blood bank information illustrated below shows the interaction between the system components.

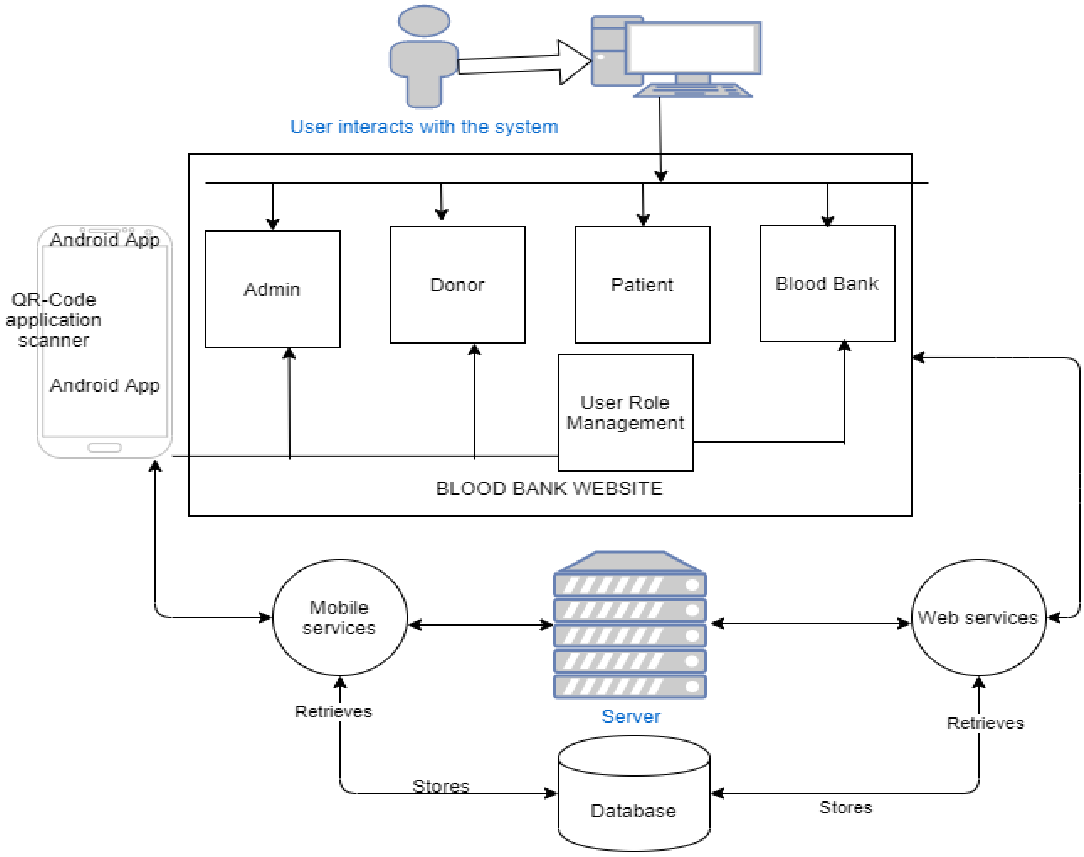

Figure 4.1: System Architecture

4.5 System Design

4.5.1 Context Diagram

The context diagram illustrates the users of the system and how they interact with the system. The diagram is read from left to right therefore illustrating the systematic flow of the system.

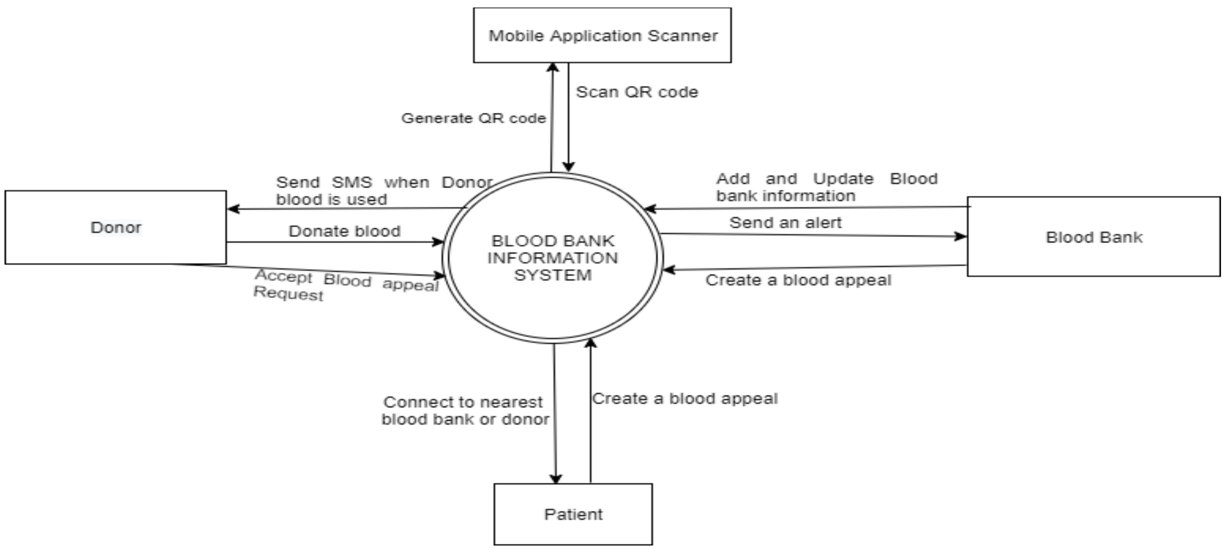

Figure 4.2: Context Diagram

4.5.2 Level 1 Data Flow Diagram

The Level 1 diagram is more illustrated showing all the processes that the system undergoes and how they relate with the users. It also shows the data stores where information is stored.

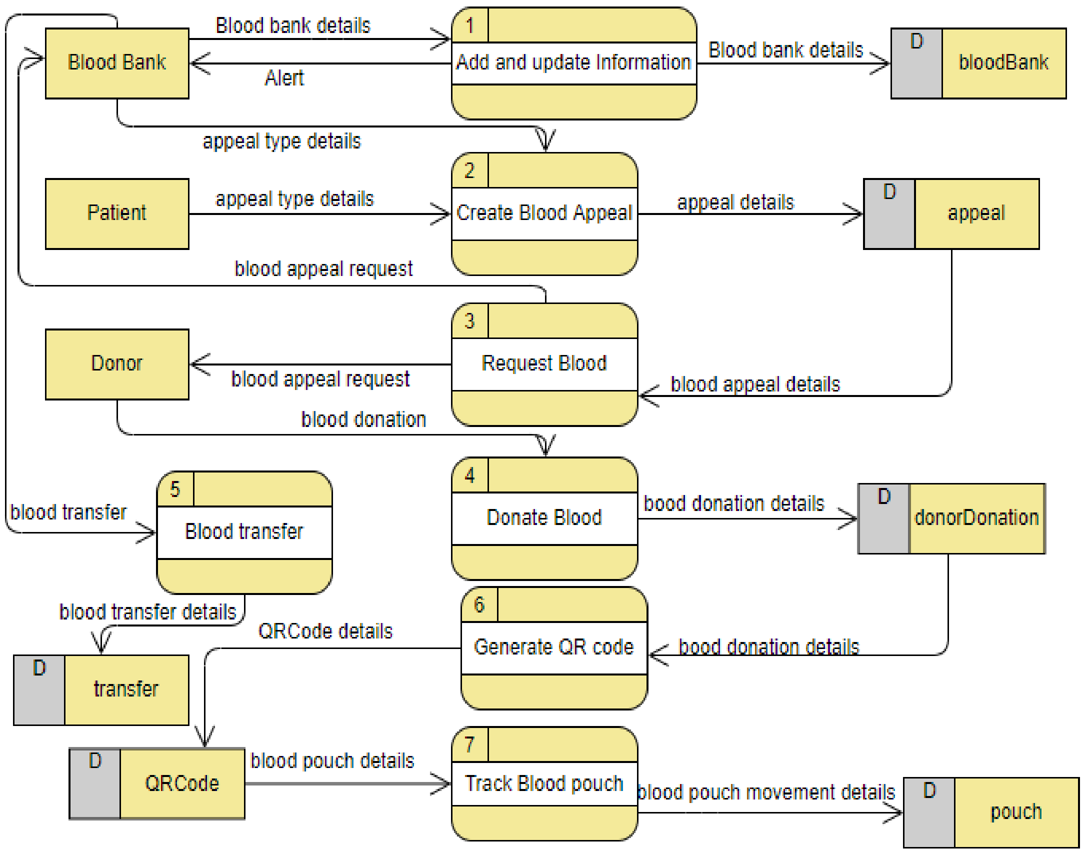

Figure 4.3: DFD Level 1 Diagram

4.5.3 Level 2 Data Flow Diagrams

The level 2 diagrams breakdown each process separately illustrating what happens in each process in the level 1 diagram above.

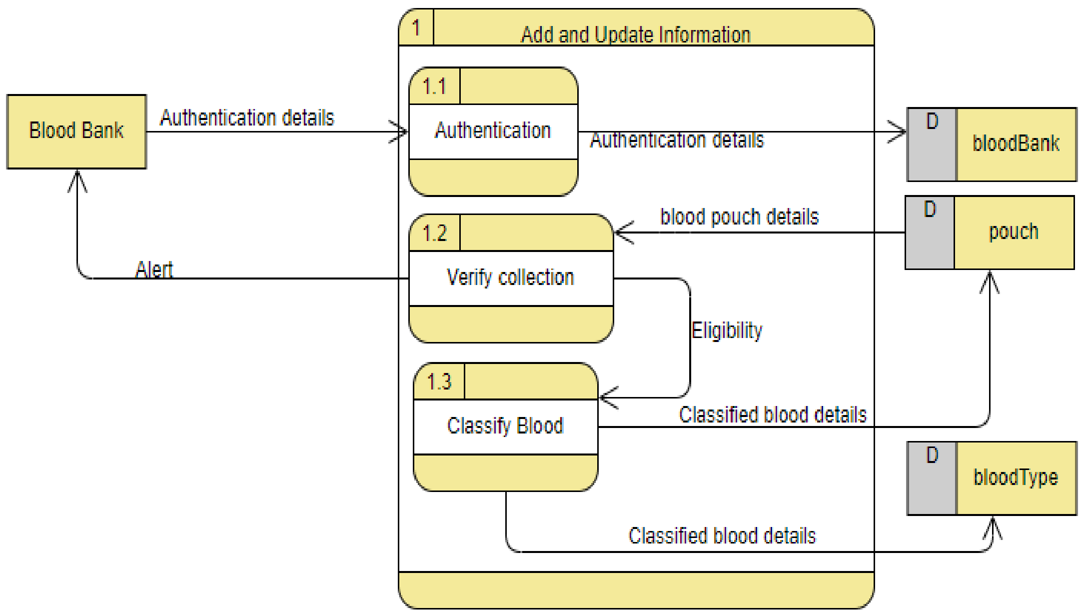

Figure 4.4:Level 2 Diagram - Add and Update Information process

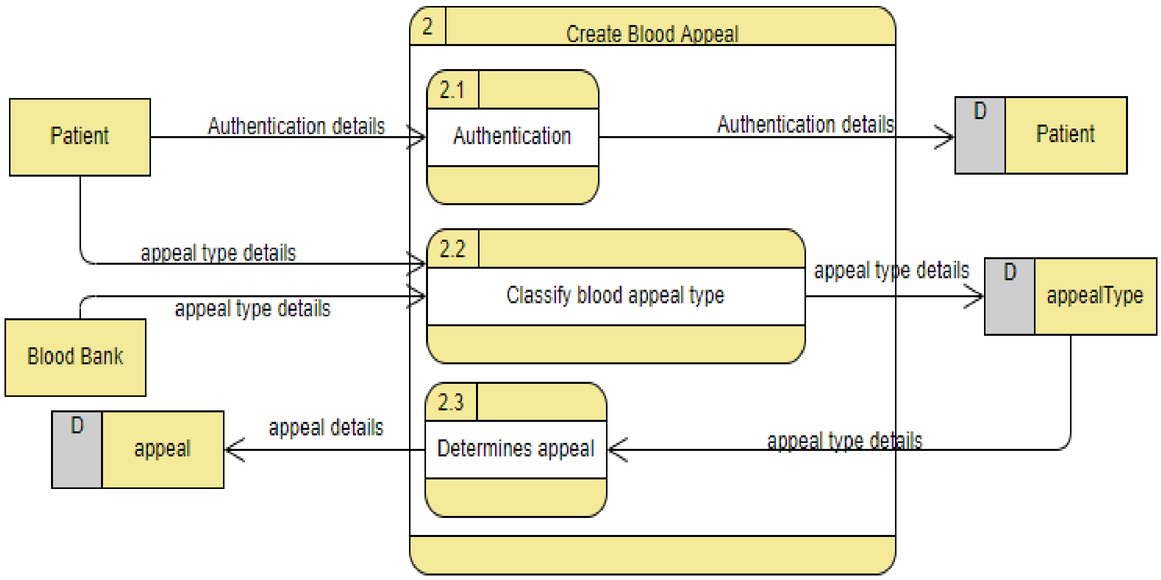

Figure 4.5:Level 2 Diagram - Create Blood Appeal Process

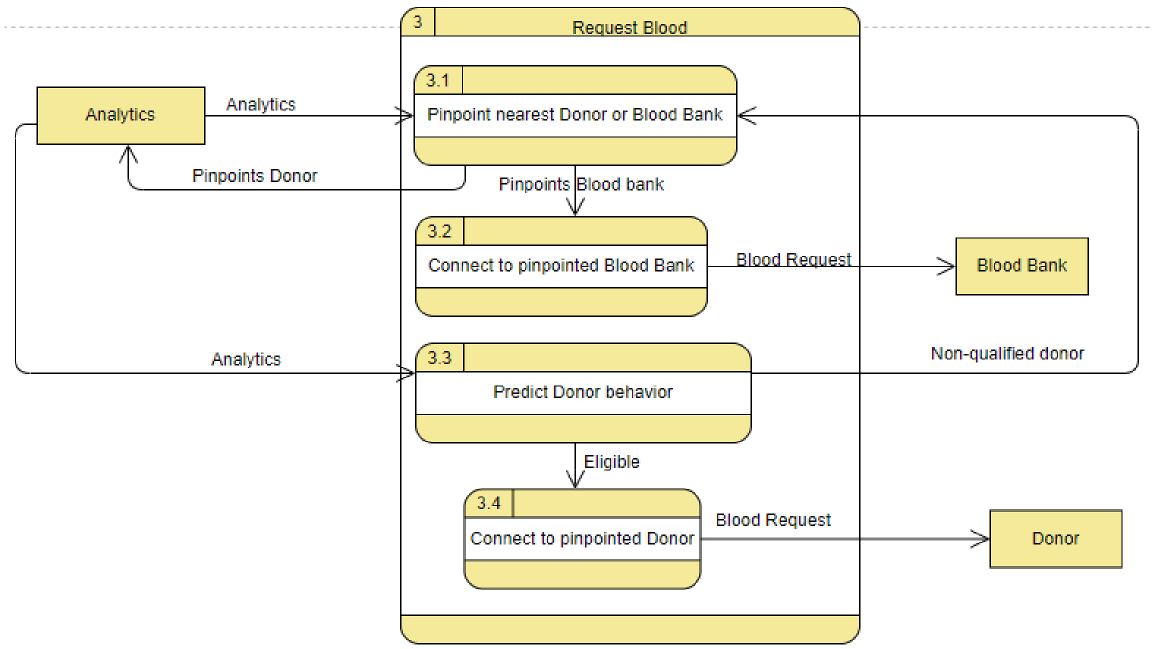

Figure 4.6: Level 2 Data Flow Diagram - Request Blood Process

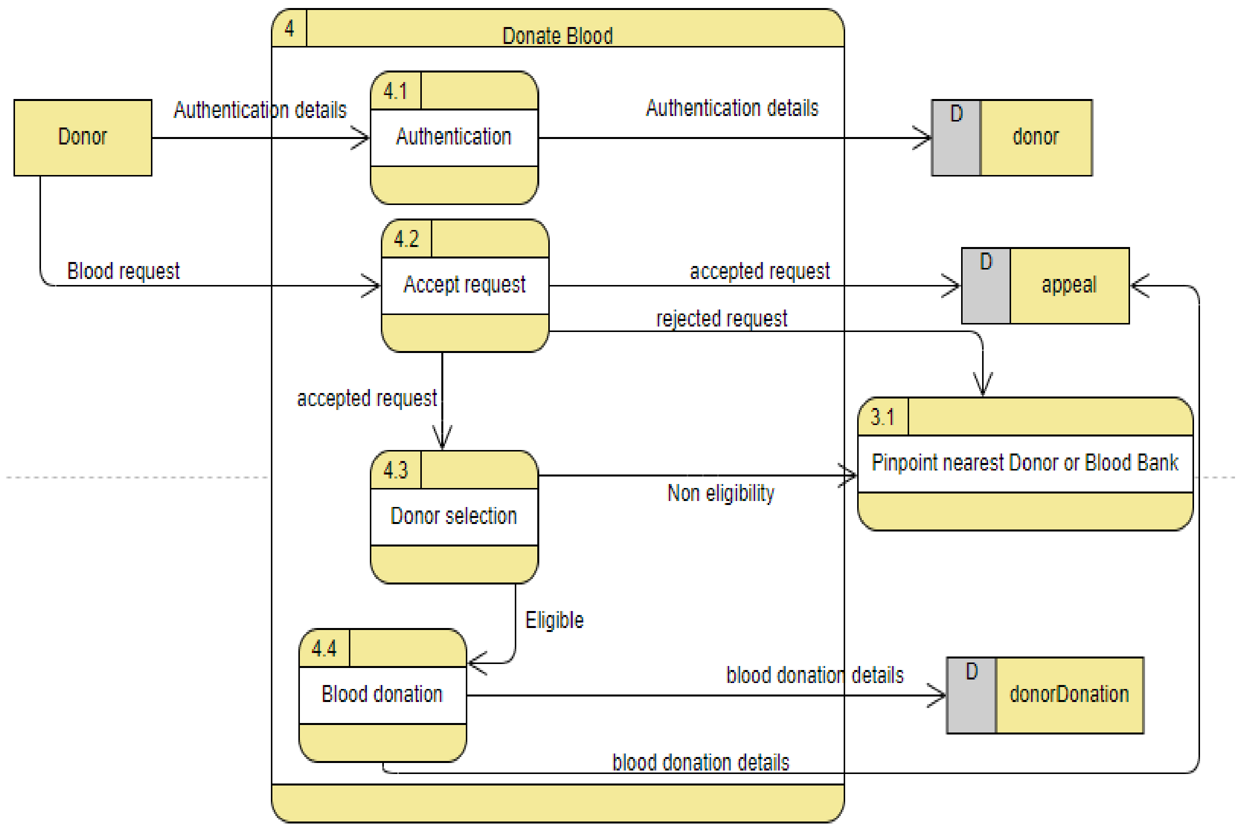

Figure 4.7: Level 2 Data Flow Diagram - Donate Blood Process

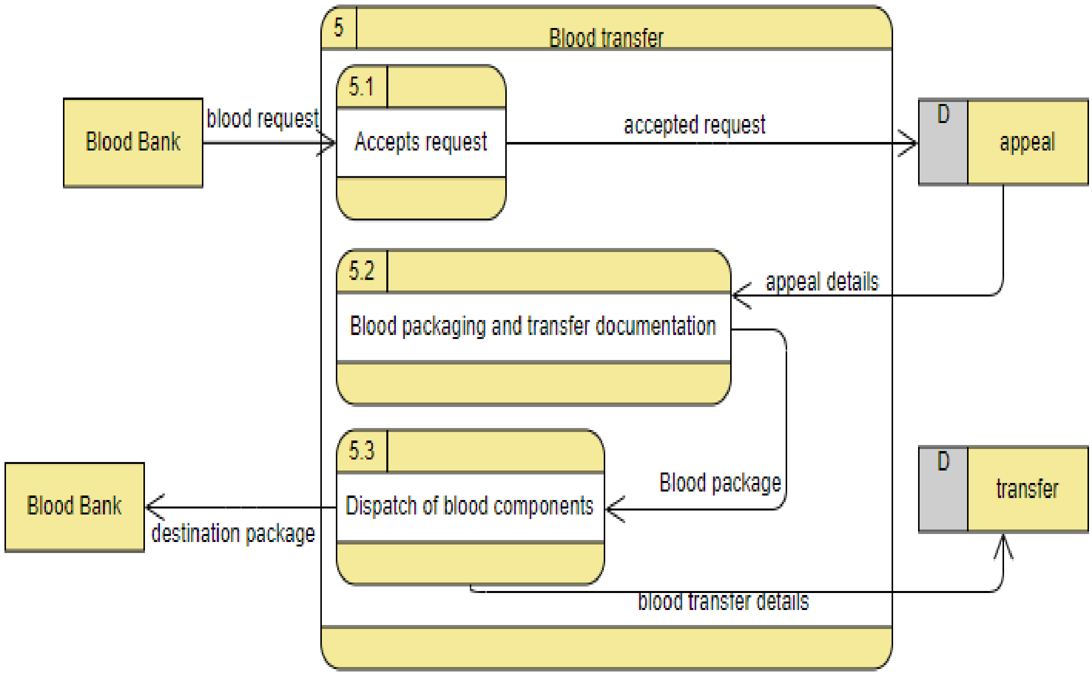

Figure 4.8:Level 2 Data Flow Diagram - Blood Transfer Process

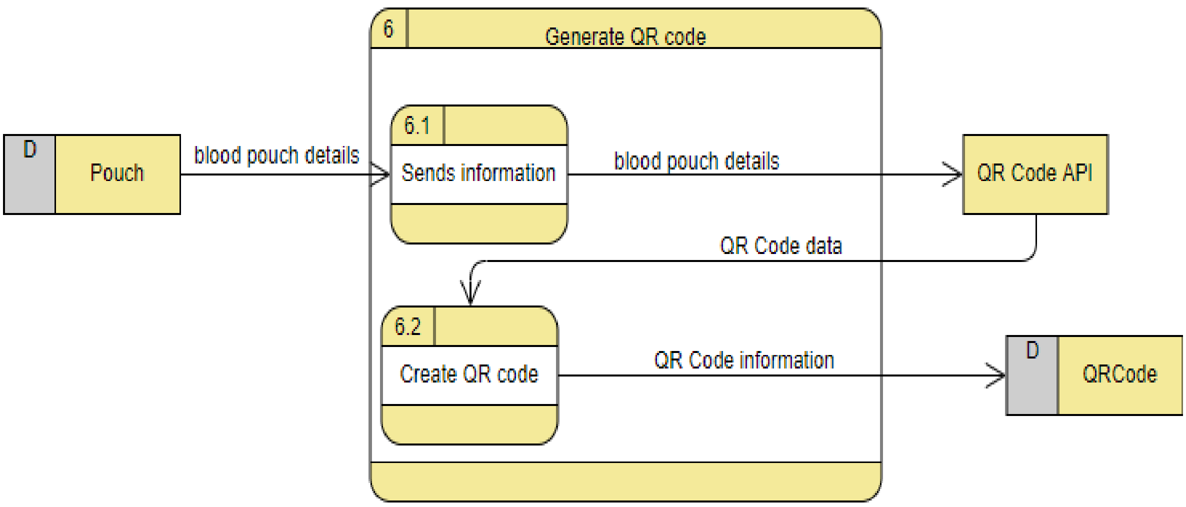

Figure 4.9: Level 2 Diagram - Generate QR Code

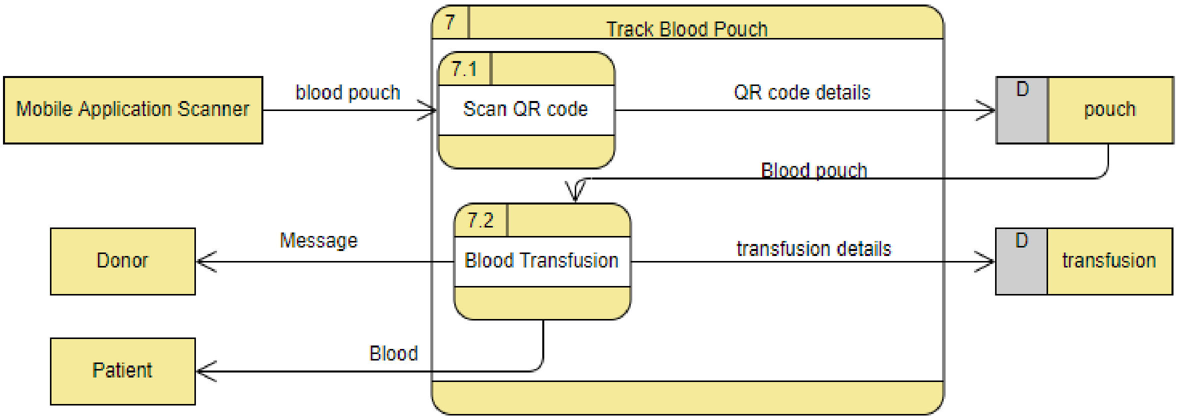

Figure 4.10: Level 2 Data Flow Diagram - Track Blood Pouch Process

4.5.4 ERD

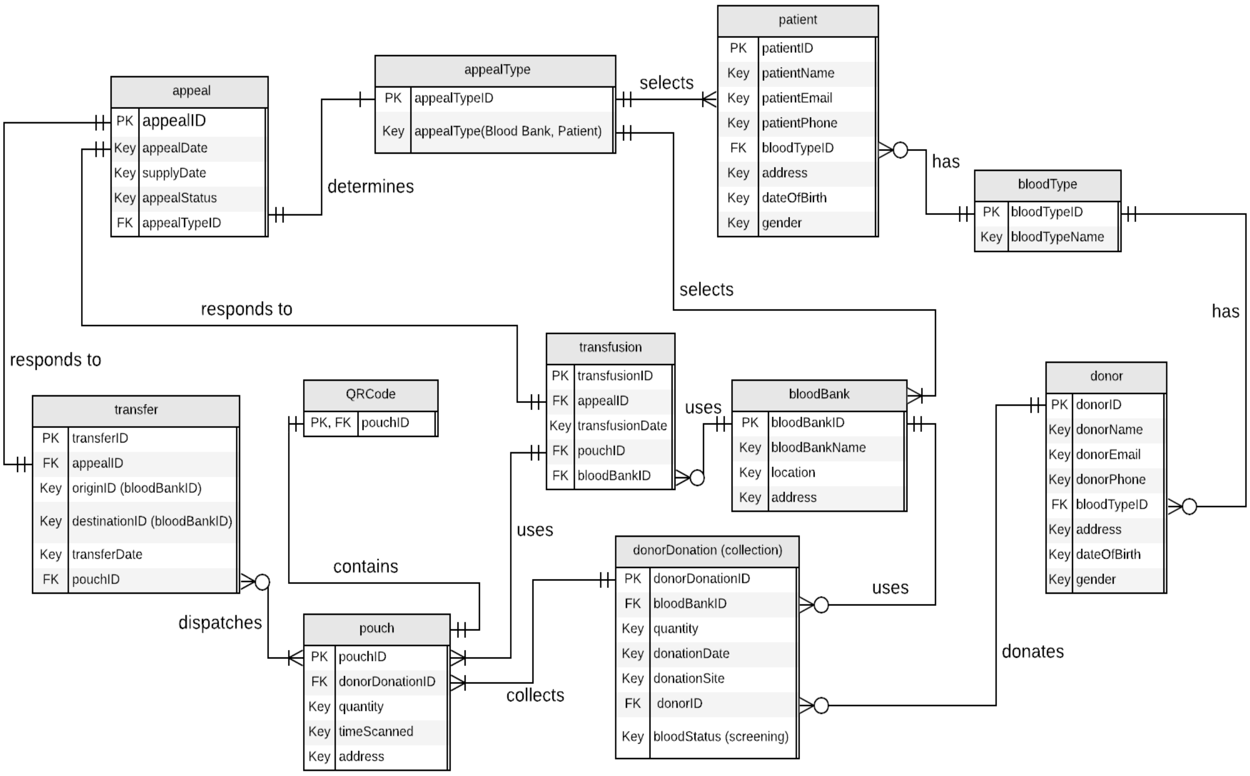

Figure 4.11:Entity Relationship Diagram

4.5.5 Database Schema

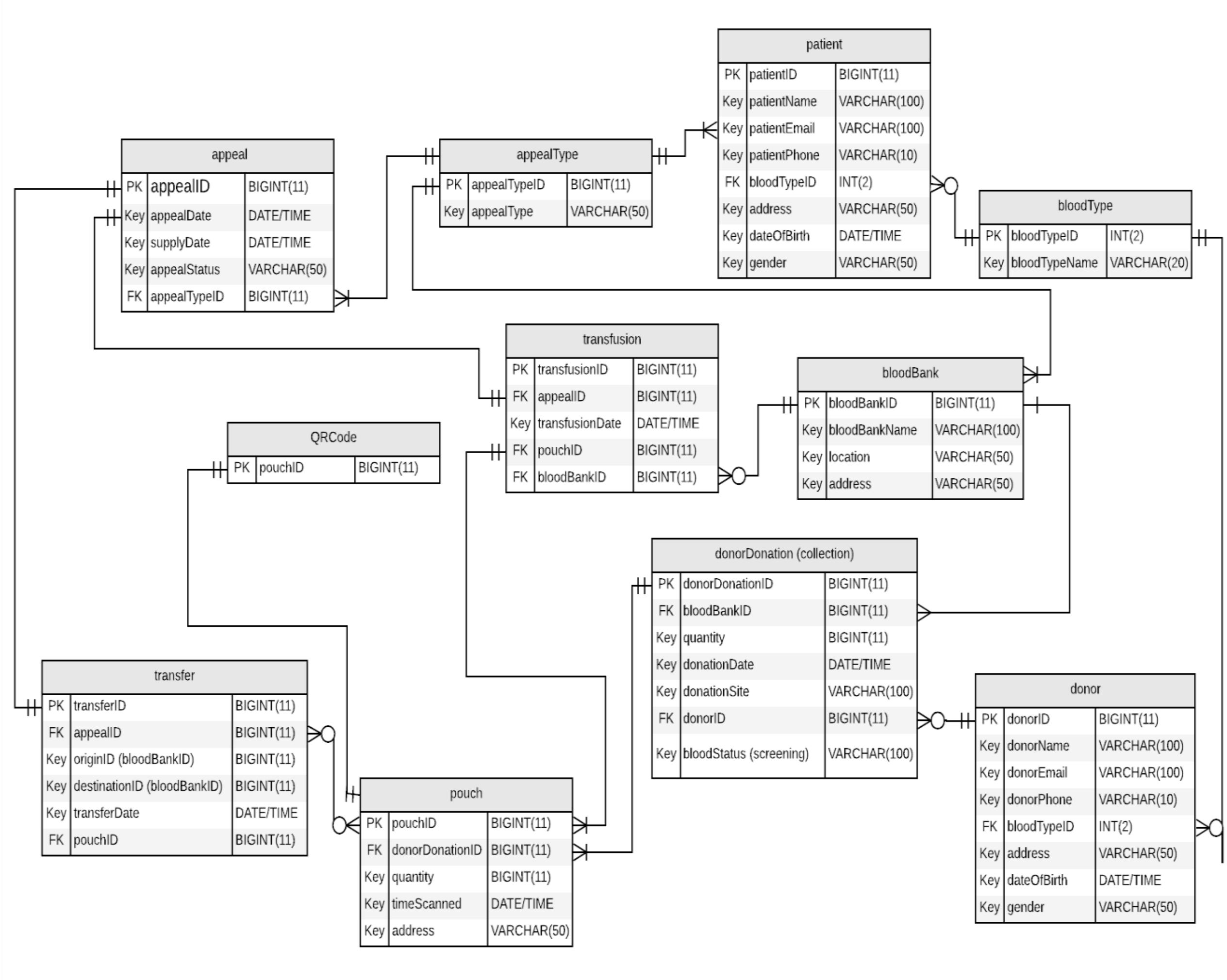

Figure 4.12: Database Schema

Chapter 5: System Testing

5.1 Introduction

System testing is the process of executing a program with an intend of finding errors often used to achieve verification and validation process. Hence, this system developed has been compared its actual behaviour against expected behaviour. In this developed system, inputs were presented to the program and examined corresponding outputs. When the tests did not tally then an error had been detected. The program test cases are based on the system specification, such as the functional requirements. Testing is an important phase in software development because it finds errors and failures by identifying and removing faults.

5.2 System implementation

At the start of the system development, there was the observation and identification of the different actors that will take part and will be involved directly in using the system. The main actor identified at the start of the system development is the blood bank and the patients themselves. The super admin is another actor in charge of the system as a whole and making sure that the database is under proper maintenance. The super admin also restricts the views of each module and also is the one who generates the various reports. The blood donor is another actor that is registered into the system by the blood bank admin. They login the system using credentials sent to them by the admin through email.

The next stage of the system development was identification of the different modules that will be of greater importance to the different actors in the system and putting in mind that the two main actors will have different modules that they will fully interact with at different levels. The most important activity for the patient will be to register into the system and create a blood appeal and for the blood bank, it will be to log in the system and perform blood donations as well as generate QR Codes. The blood bank also creates a blood appeal to both a different blood bank and donor. It is also responsible for updating blood status, i.e. whether it has been transfused into a patient or transferred to a different blood bank through the aid of the android based mobile application system.

The construction and development of the web - based system was done using PHP Laravel Framework due to the fact that it is a website and thus will be easy to come up with the system using the above-mentioned language. The mobile-based application was developed using Java language. The different types of design diagrams make it easy to identify how the system will work and also makes it easy identify the process flow of information throughout the system thus proving very helpful to the developer. System requirements were earlier identified and were structured into the system. Using the proposed system development methodology, it proved easy and more applicable to develop the system by prototyping and developing each module at a time.

On completion of the different module development they were later linked to come up with the system as a whole. In the process of linking the different modules it was important to maintain the logic of the system in that it was of essence to make sure that they all link together in a manner that is understandable and consistent. This means that on the click of a button the button should redirect to the next stated page and not a page that previously came before it.

5.2.1 Mock-ups

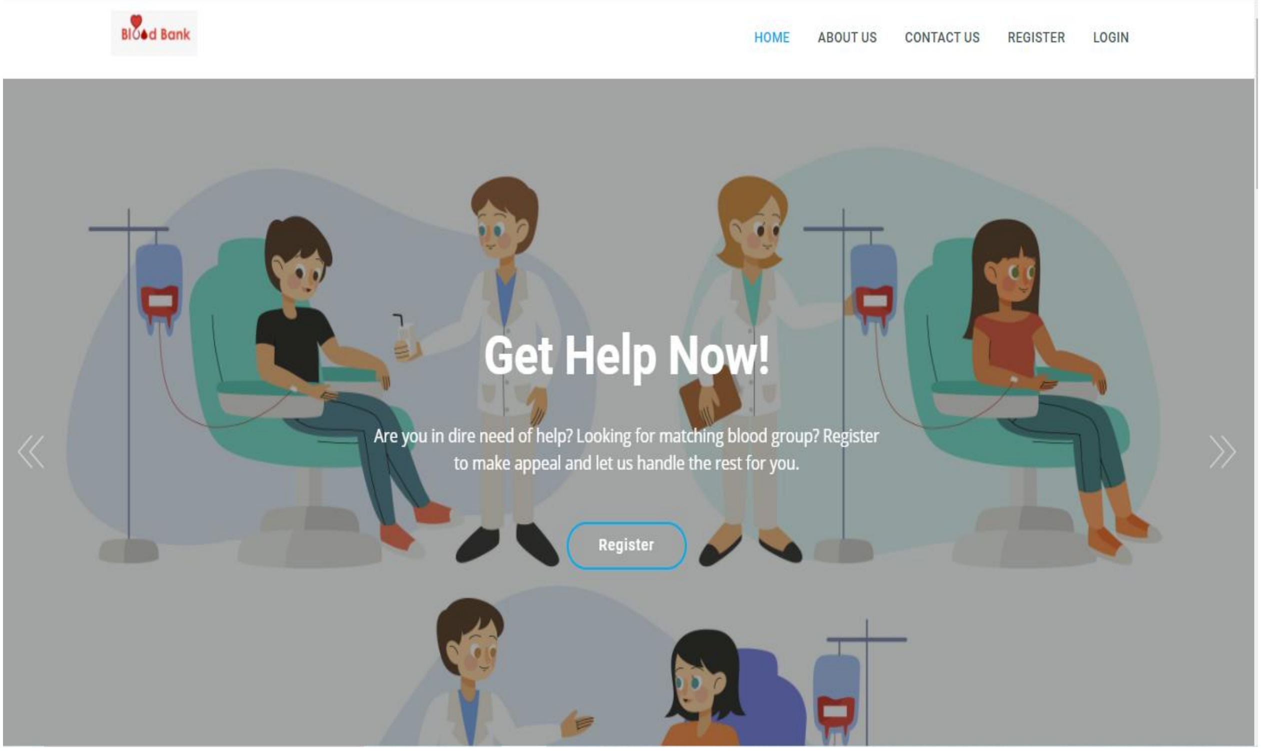

Figure 5.1: Homepage

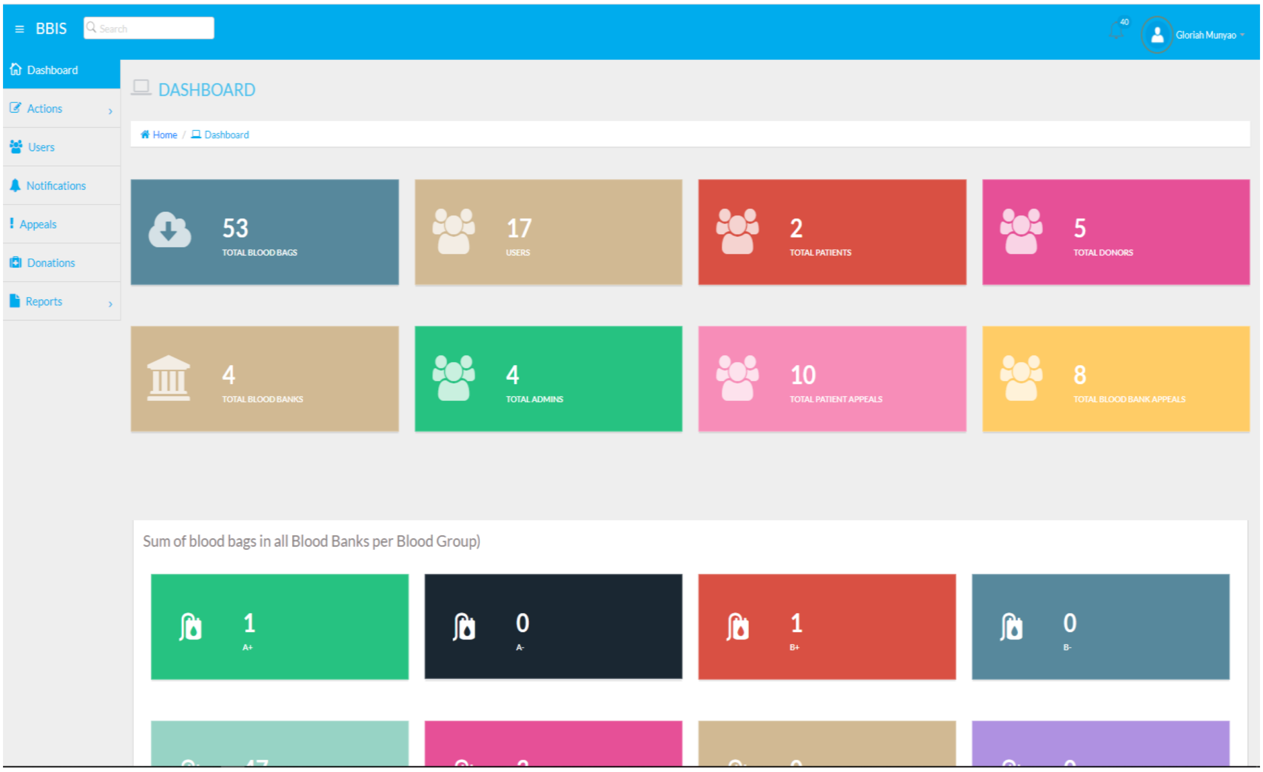

Figure 5.2:Admin Dashboard

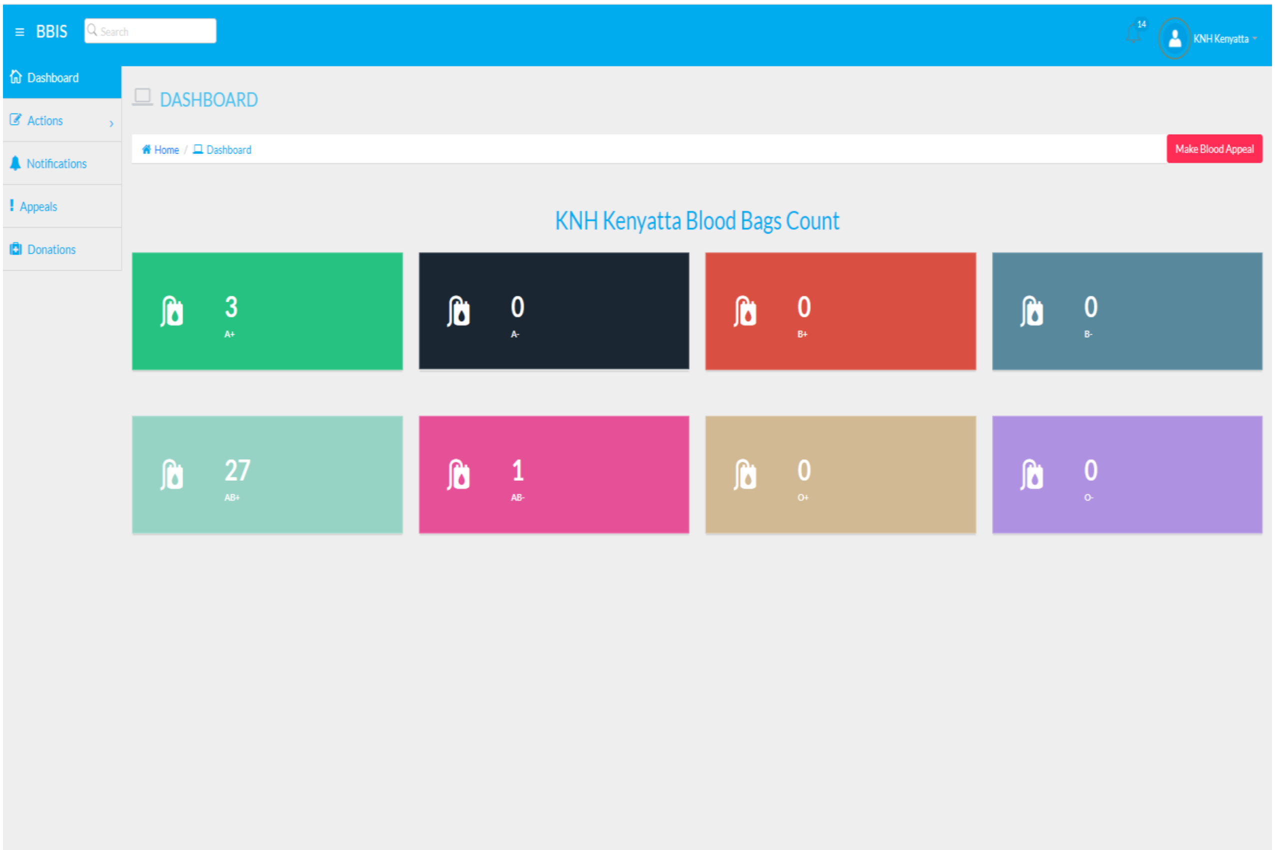

Figure 5.3: Blood Bank Module

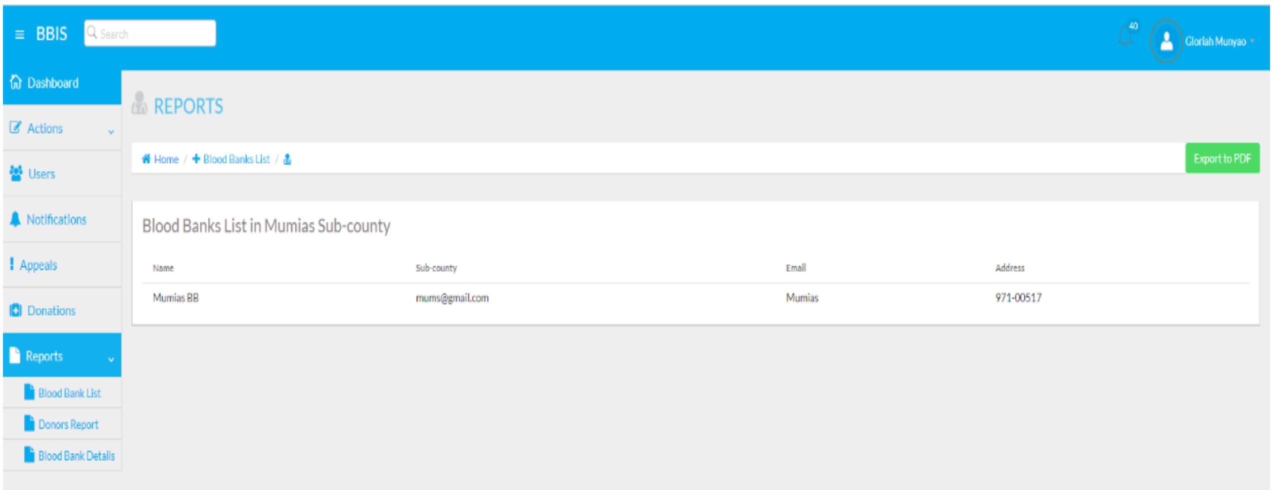

Figure 5.4: Example of a Report Generation Form

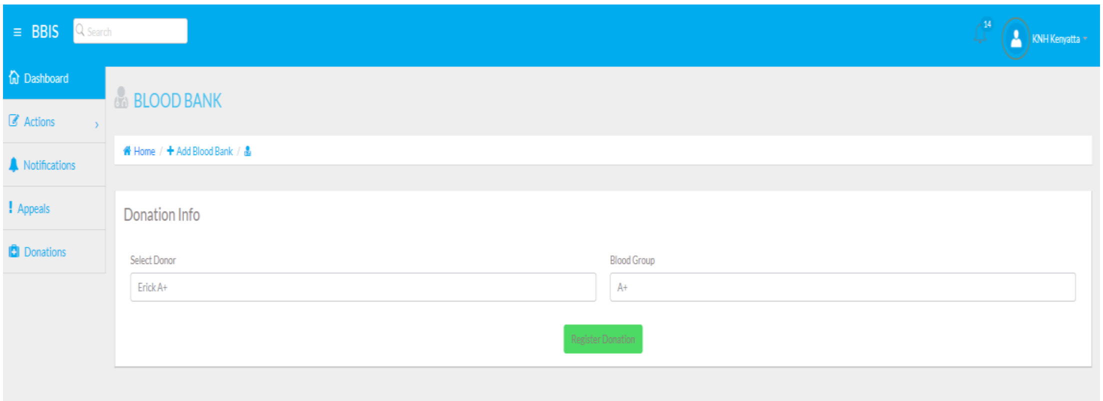

Figure 5.5: Blood Bank Create Donation Form

5.3 Test Environment

The web application system was developed and designed using specific software and hardware conditions that led to its successful implementation.

5.4 Software Requirements

Software	**Description**
Operating System	Microsoft Windows 10 Home Single Language Version 10.0.19041
Relational Database Management System	mysqlnd 7.4.10
Programming languages	Laravel

Internet Browser	Google Chrome, Microsoft Edge, Internet Explorer, Mozilla
Integrated Development Environment	Visual Studio, Android Studio
WampServer	Apache Server with MySQL database

Table 5-1:Software Requirements

5.5 Hardware Requirements

Hardware	**Description**
Processor	Intel(R)Core(TM)i3-6006U
Memory	4.00GB RAM
CPU clock speed	2.00GHz
Resolution	1366 × 768 (Recommended)

Table 5-2: Hardware Requirements

5.6 Test Cases

Test ID	**Related Requirement**	**Inspect check**	**Precondition**	**Test data**	**Priority test**
T1	FRQ1	Does the system allow the super admin, blood donor, patient, and blood bank to login	There should be a login form available for the user who is only already registered	Registration First name: Grace Last name: Njoroge Phone number: 07123456 Email: gracen@gmail.com Password: ***** Login Email: gracen@gmail.com	Very High

		upon registration?		Password: *****	
T2	FRQ2	Does the system alert relevant authorities when there is a surge?	There should be available data in the blood bank module	Data stored from the donations and blood banks database table	Very High
T3	FRQ3	Does the system trail at what place and time a QR code was scanned to enhance security?	The user should have sent back processed data from the android application to web system after scanning a QR code	Data stored from the QR code database table	High
T4	FRQ4	Does the system capture and store donors', blood banks', and blood bank inventory details into the My Structured Query Language (MYSQL) database?	The respective users should add information in their respective modules	None	High
T5	FRQ5	Does the system generate pre-defined reports such as the list	There should be available data to process the reports	Data stored from the database	High

		of donors, recipients, and blood quantity in the bank?			
T6	FRQ6	Does the System allow administrators to delete, add and update data, blood bank inventory as predetermined by the transfusion center procedures?	There should be CRUD functionalities in the admin module	Data stored from the blood bank database table	High
T7	FRQ7	Does the system allow the blood donor and blood bank to view blood request alerts?	Notifications should be sent to the blood donor and blood bank upon request	Notification sent to blood donor and blood bank module	High
T8	FRQ8	Does the system allow the blood donor to view his/her donation history?	There should be a profile on the donor module with donation history	Data stored on the donations database table should	High
T9	FRQ9	Does the system allow the admin in a blood bank and the patient	There should be a create appeal form available	Data stored from appeal database table	High

		to make a blood appeal?	to the patient and blood bank		
T10	FRQ10	Does the system allow the blood bank and patient to view their profile?	There should be an available user profile in the blood bank and patient module	Data stored from the blood bank and patient database table	Medium
T11	FRQ11	Does the system allow the super admin to view blood alert responses?	Notifications of blood request alerts should be available on the super admin module	Blood appeal request alert notifications after clicking the notification bell icon on the super admin module	Medium
T12	FRQ12	Does the system allow the blood bank, patient, super admin, and donor to edit his/her profile?	There should be CRUD functionalities on the blood bank, patient, super admin, and donor profile pages.	Edit profile on their profile page	Medium
T13	NFRQ1	Is the system reliable in that when an individual wants to access information from the system, it should be	The user should have submitted registration input into the system	Username: tester Password: t3sT1	High

		available to the users?			
T14	NFRQ2	Is the storage capacity of the system big enough to store all the information needed for a large group for a long period of time that will enable the system to run faster?	There should be an available database	Data needed to be stored	High
T15	NFRQ3	Is the System's Database code reusable and exported into a library?	An existing PDO database connection code	None	None

Table 5-3: Test Case

5.7 Test Results

Test ID	**Expected result**	**Actual result**	**Status**	**Remarks**
T1	The system should allow the user to login if they are already registered.	An already registered user can login to the system and view their authorized pages	Pass	No remarks
T2	The system should send a	A notification is sent to the super	Pass	No remarks

	notification to the super admin when there is a blood surge in a blood bank	admin when blood has overstayed their shelf period in a blood blank		
T3	The android application system should send back the location and time data after processing the scanned QR Code	The android application does not send back any information to the web- based system after scanning the QR code. It only reads the data but does not interact with the website.	Fail	The android application is not linked to the web- based system
T4	The donor's and blood bank's database table should store all information from the donor and blood bank modules	The donor's and blood bank's database table stores all the information from the donor and blood bank modules	Pass	No remarks
T5	The system should produce reports such as, the list of donors, recipients, and blood quantity in the bank	The system generates reports such as, the amount of blood in a blood bank per blood group, a list of blood banks per	Pass	No remarks

		location and donations per blood bank		
T6	The system should allow admin to perform CRUD functionalities on blood bank inventory	The admin can perform CRUD functionalities on blood bank inventory	Pass	No remarks
T7	The system should allow the blood donor and blood bank to view blood request alert notifications on their page	The blood donor and blood bank can click on the notification bell on their page to view blood request alert notifications	Pass	No remarks
T8	The system should allow a donor to view their donation history	The donor can view their donation history on their profile	Pass	No remarks
T9	A blood bank admin and patient should be able to create a blood appeal	The system enables a blood bank admin and donor to create a blood appeal automatically if their blood information is available	Pass	No remarks

T10	The system should have a profile page for a blood bank and patient and allow them to view it	A blood bank and patient can click on their profile page in their dashboard and view it	Pass	No remarks
T11	The system should enable the super admin to view all blood alert responses	The super admin can view all blood alert responses on their dashboard after clicking the notification bell	Pass	No remarks
T12	The system should allow all modules to edit their profiles	All modules can edit their profiles through the CRUD functionalities available	Pass	No remarks
T13	The system should be reliable in that when an individual wants to access information from the system, it should be available to the users	Information is accessible when required by a user	Pass	No remarks
T14	The storage capacity of the system should be	The system can store lots of information	Pass	No remarks

	big enough to store all the information needed for a large group for a long period of time that will enable the system to run faster			
T15	The system's database code should be reusable and exported into a library	The database can be reused	Pass	The Laravel framework migrates the database

Table 5-4: Test Results

Chapter 6: Conclusion and Recommendations for Future Work

6.1 Introduction

The main objective of this project was to construct a Blood Bank Information System for the Ministry of Health in Kenya. This set off with the evaluation of the current systems; establishment of user and or business requirements that aided in specifying the functional and non-functional requirements that were used to design models from which the prototype for a new solution was implemented. This chapter lays down the researcher ‘s conclusions after the implementation of the solution, recommendations and hints on future plans regarding the developed system.

6.2 Conclusion

This work provides an analysis and evaluation of the current and prospective computerized solutions in the health sector in Kenya. This study uses a case of the Kenya National Blood Transfusion Services, where there is still lack of a computerized technology and sustainable blood donation strategies to perform all its duties, one of which is to, monitor and evaluate the standards in respect of blood donation, processing, movement and distribution of blood for the purpose of efficient blood transfusion.

The first objective was to analyse current blood donation strategies used in blood banks in Kenya. Reviewing of documentations was the method used by the researcher to identify the current blood donation strategies being used at Kenya National Blood Transfusion Service. The researcher identified that KNBTS uses a manual Blood Bank Management System and that most of the processes including record keeping and inventory control are manual. Each blood bank maintains its own records although KNBTS lacks a central location from which records from the various banks can be accessed. This encouraged the researcher to go ahead with further investigates anticipating smooth collaboration with various users who are already familiar with computerized health applications.

The second objective of this project was to review blood bank information systems in Kenya. Clearly, as we can infer from the first objective, the current system is a cumbersome one. In order to achieve this objective the researcher reviewed most reputable blood bank information systems and identified one in Kenya called “RedSplash Application” which is currently being used to avail safe and free blood to patients who require transfusion treatment in a timely manner without any discrimination. As already explained in chapter two of this document, the strategies used include; a share button placed in each appeal to enable the message to be disbursed to various social media platforms, display of a due donor and rates if the donor is willing to donate blood, a blog that talks on health and fitness topics while creating the importance of donating blood, sending of thank you notes to donors through an SMS once their blood has been used to save a life. This application led to the researcher to suggest a hybrid system of an android and web-based application. The choice came about when the researcher realized that Kenya not only wants a system that will solve its blood donation problem but also its blood shortage crisis.

This realization led to the third and final objective. The researcher was motivated to add more functionalities and blood donation strategies to assist in the current problem facing Kenya through the development of an updated Blood Bank Information System. The development was followed by its functional testing which revealed the working and non- working functions. Some of the latter, the researcher managed to solve, and the rest have been included in future works.

The core coding for the mobile interfaces was written with Java while the backend for the administrator was written with Laravel which the researcher found easier compared to PHP itself that caused challenges. MySQL was the database management system used for its standardization as well as low cost for maintenance, migration, and upgrades.

In conclusion, this project represents a careful and systematic effort to investigate further blood and blood donation possibilities, particularly in Kenya.

6.3 Recommendations

Regarding the main problem in monitoring and evaluating the standards in respect of blood donation, processing, movement, and distribution of blood for the purpose of efficient blood transfusion, this project approves the adoption of a web and android application system that it has developed. This is because it can solve the current trends in Kenya concerning blood donation and offer a platform where the main stakeholders, that is blood banks, donors and patients, can interact with the system and get quality services in their quest for blood and blood donation. The blood bank information system can be of great significance to the Ministry of Health of Kenya as it enables them to monitor and evaluate the standards in respect of blood donation, processing, movement, and distribution of blood step by step. The other important role that the system would play is that it would help the Ministry to adequately allocate resources fairly as information would be stored securely in the system's database.

From the analysis taken in regard to the project variables which include time, cost and the scope, the methodology used in developing this system is prototype methodology. The methodology involves minimal planning unlike other methodologies which takes planning as a phase and it also allows for incorporation of changes with development process which in turn makes iteration possible in all the phases.

In conclusion this project recommends the adoption of the system developed to the industry as it would help solve problems associated blood and blood donation in the country as mentioned above and in the long-run make the country's health sector more reliable.

6.4 Recommendations for Future Work

This project recommends the predictive analytics technology which it failed to integrate with the developed system. The business intelligence technology would make the system more user – oriented since it would be able to predict when blood is going to be needed in the country. Therefore, the Ministry of Health would be able to beforehand plan to cater for those needs through ways such as distributing resources to the various blood banks in the country.

The developed system also failed to use the Google Maps API to pinpoint the nearest blood bank or donor. The API would be a better method that this project recommends rather than pinpointing using available blood banks in a sub county. The actual nearest location would not be pinpointed since distance is not a factor in the developed system hence the need for the Google Maps API.

The developed system was not tested in the industry's environment which is a future recommendation. Proper feedback from the Health sector would improve the solution provided thus leading to the Ministry of Health accepting and utilizing the developed system.

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Appendix A: Timeline of Activities

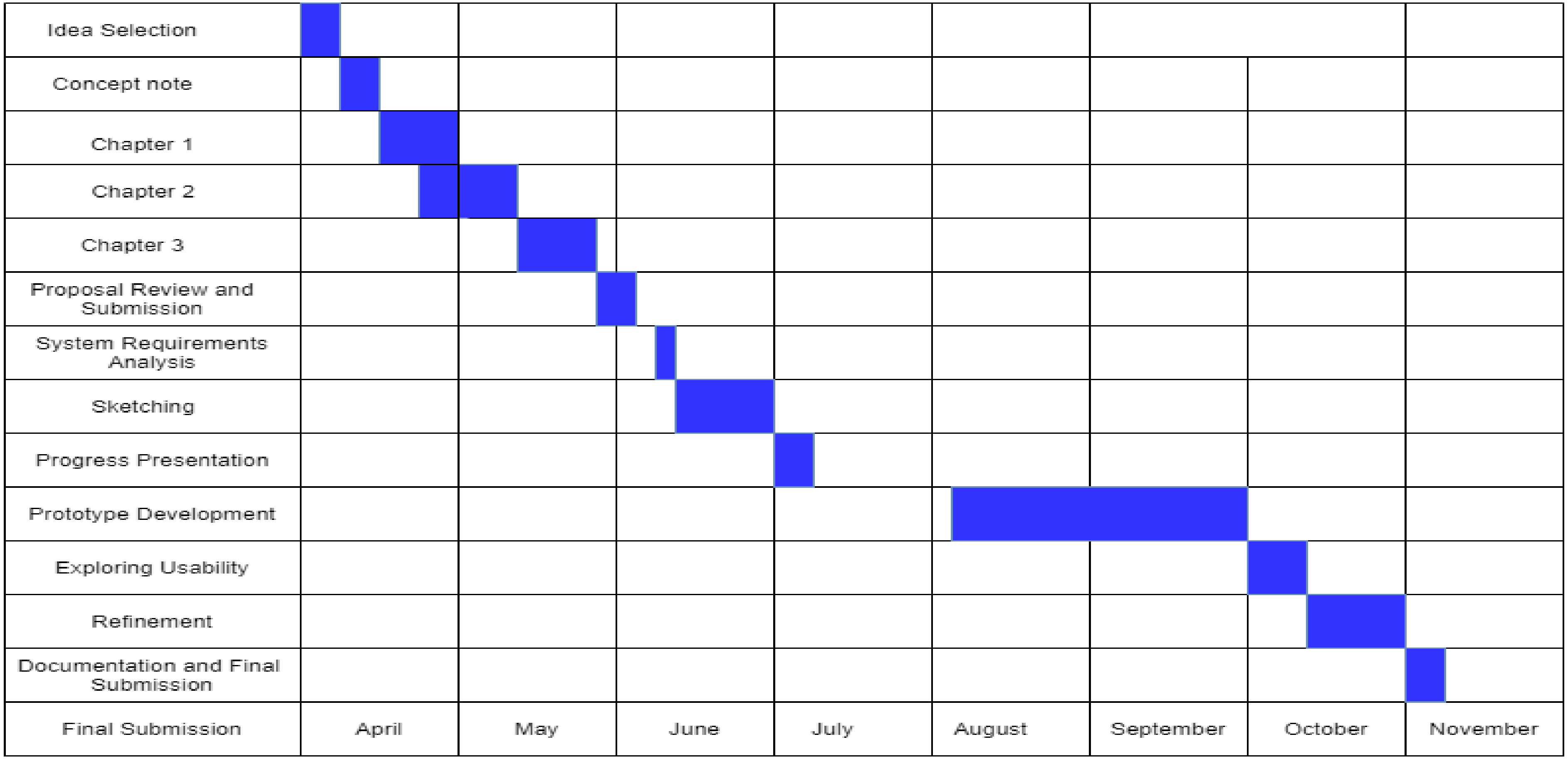

Figure 6.1: Gantt Chart

Appendix B: User Manual Guide

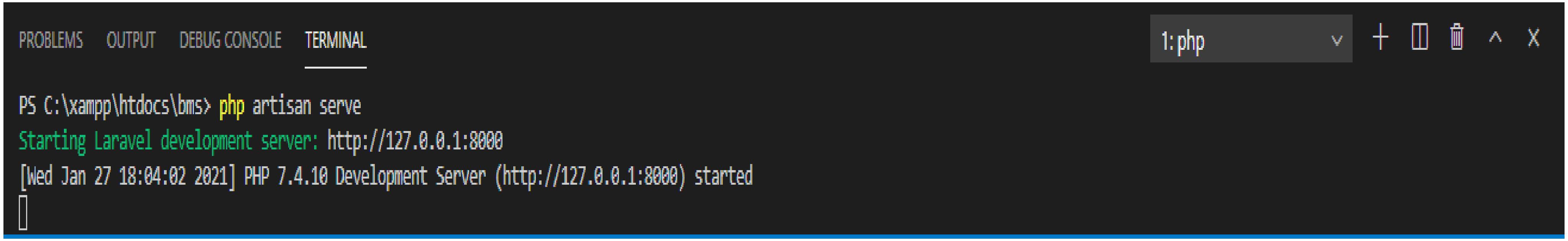

Figure 6.2: Visual Studio Terminal

In order to start the system, the user adds the command "php artisan serve" to their editor terminal. A user can use either Visual Studio or Git Bash. After running the command, the user should click on the link provided such as the one on the diagram. The follow link will open the Laravel system developed.

The user has to make sure their Xampp Server is running by pressing on the start button on both the Apache and MySQL module. The diagram below is the Xampp control panel where the user will start the server.

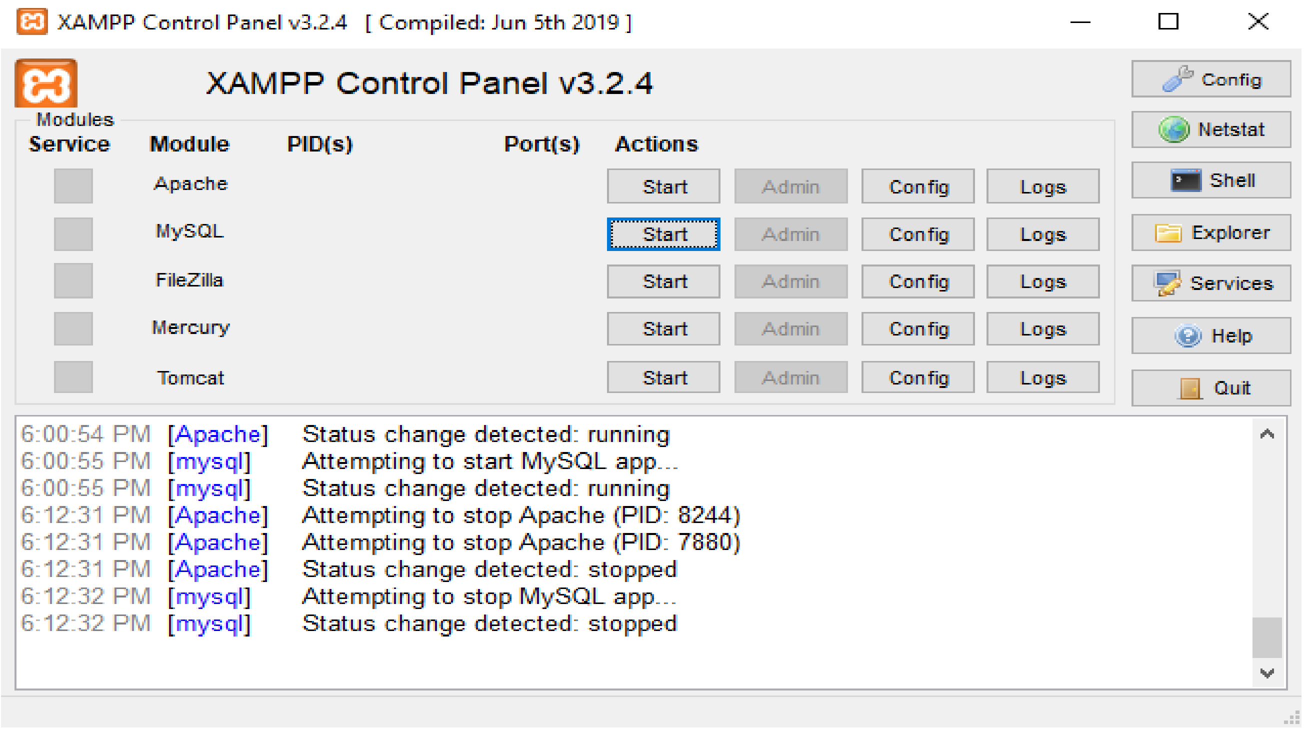

Figure 6.3:Xampp Control Panel