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THE IMPACT OF INFORMATION TECHNOLOGY ON REVERSE LOGISTICS OF BLOOD IN PUBLIC HEALTHCARE FACILITIES IN THE GAUTENG DEPARTMENT OF HEALTH

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A thesis submitted in fulfilment of the requirements for the degree of

Masters in Information Systems

In the Department of Information System

Faculty of Economics and Management Sciences

University of Western Cape

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13 FEBRUARY 2023

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Abbreviation	Meaning
AIT	Automatic Identification Technology
ASCO	American Society of Clinical Oncology
BRB	Blood Returnable Basis
BTB	Blood Transfusion Book
CDR	Clinical Data Repository
CDS	Clinical Decision Support
CLSC	Closed-Loop Supply Chain
CPOE	Computerised Provider Order Entry
CSR	Corporate Social Responsibility
CT	Communication Technology
CT	Computerised Tomography
EDI	Electronic Data Exchange
eMAR	Electronic Medication Administration Record
EMRAM	Electronic Medical Record Adoption Model
ERP	Enterprise Resource Planning
ESQ	Electronic Survey Questionnaire
GDoH	Gauteng Department of Health
GDP	Gross Domestic Product
GGT	Growing Gauteng Together
GP	Gauteng Province
GSDH	Global Strategy on Digital Health
Hb	Haemoglobin
HIE	Health Information Exchange
HIMSS	Healthcare Information and Management Systems Society
HIS	Health Information System
HoD	Head of Department
ICD	Classification of Diseases
ICU	Intensive Care Unit
IT	Information Technology
MRI	Magnetic Resonance Imaging
MSBOS	Maximum Surgical Blood Ordering Schedule
MTEF	Medium-Term Expenditure Framework
MTP	Massive Transfusion Protocol
OPD	Outpatient Department
OS	Organisational Strategy
PACS	Picture Archiving and Communication Systems
PBM	patient blood management
PHC	Primary Healthcare
PHF	Public Healthcare Facilities
RBC	Red Blood Cells
RFID	Radio Frequency Identification
RL	Reverse Logistics
SA	South Africa
SANBS	South African National Blood Service
SC	Supply Chain
SCL	Supply Chain Logistics
SCOR	Supply Chain Operations Reference
SDG	Sustainable Development Goals
SOP	Standard Operating Procedures
TRL	Technological Readiness Level
UHC	Universal Health Coverage
UN	United Nations
US	United States
WHO	World Health Organisation

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Abstract

The South African National Blood Service (SANBS) estimates that over 900,000 blood units are collected yearly from 1% of the population of South Africa (SA) actively donating blood, but 40% of the donated blood is estimated to be wasted across public healthcare facilities. As a result, surgical procedures have been cancelled or postponed, putting patients' lives at risk. This waste has been attributed to poor logistics of blood products between South African National Blood Services (SANBS) and hospitals, lack of technology to facilitate the logistics of blood products, and poor infrastructure to support the return of unused blood within the regulated period. Furthermore, blood products such as red blood cells (RBC) are prone to high wastage due to patient passing before blood transfusion, patients discharged with blood already ordered and delivered, patients refusing blood transfusion due to religious affiliation, change in Hb levels before transfusion, and poor coordination between health workers that results in limited communication during delivery of medical services. This study maps the reverse logistics (RL) process for blood products in public healthcare facilities (PHF) to identify barriers to implementing the RL process in PHF and the key factors driving the waste of blood products and recommends implementing a technological solution and reverse logistics processes for the logistics of blood products to reduce blood waste. Transporting blood in brown bags and mapping current logistical processes for blood products in on-site and remote blood bank hospitals reveal gaps that prevent returning unused blood products to blood banks. This study focuses on medical professionals, where various blood products (red blood cells (RBC), fresh frozen plasma, and platelets) were identified for the research. A quantitative applied research approach was chosen as the preferred methodology, and a stratified random sampling method was used to select participants, stratify the population, and collect data from each subgroup.

The key findings point to a 51% waste of RBC units in the four selected hospitals, attributed to poor infrastructure to support the return of unused blood products, unstandardised processes across the similar level of care hospitals, poor logistics processes for blood products, and inefficient communication between doctors and nurses responsible for delivering medical services. The study identifies inaccurate information because of manual processes and poor monitoring of policies and guidelines as barriers to the reverse logistics of blood products. Technology and logistics methods are suggested as mitigating effects to address the above findings and reduce blood waste during medical service delivery.

The findings add to the body of academic knowledge, technology, and logistics as factors to improve the delivery of healthcare services in the public health context. They also support the recommendation that PHF uses technology to automate business processes while integrating logistics methods and models for delivering and handling blood products.

Key Words: Reverse Logistics; Supply Chain; Blood Management; Technology; Healthcare; Public Healthcare; Blood Wastage; Process Mapping; Patient Blood Management

1. Background to the Problem

The evolution of supply chain logistics (SCL) has changed over the last decade (Kumar et al., 2017; Wang, Wang & Chan, 2021), with researchers pointing out a growing need to address climate change and green supply chain logistics (Kumar et al., 2017; Jovic et al., 2020; Wang, Wang & Chan, 2021) and to identify drivers and barriers to improving SCL (Chileshe et al., 2018). Competence in reverse logistics (RL) addresses these changes (Kumar et al., 2017, Wang et al., 2021), making RL the critical competency for the management and implementation of the closed-loop supply chain (CLSC). Major industries have adopted a collaborative and integrated approach to achieve RL competency (Morgan, Richey & Autry, 2016). The approach has been imperative, as academic and industry research has linked organisational competitiveness and RL competency (Morgan, Richey & Autry, 2016; Pacheco et al., 2018; Pramono, Ulkhaq & Aulia, 2021). The current literature on RL as competency in SCL and CLSC has been extensively studied (Morgan, Richey & Autry, 2016; Wang, Wang & Chan, 2021), as further studies on the implementation drivers and barriers of RL in manufacturing and logistics (Pramono, Ulkhaq & Aulia, 2021), RL collaboration and integration (Morgan, Richey & Autry, 2016; Jovic et al., 2020). The gap in the literature has identified the need for specific research in dedicated speciality streams. Research trends in RL have focused on factors that affect the implementation of RL (barriers and drivers). RL has recently been linked to CLSC sustainability and customer satisfaction (Kazemi, Modak & Govindan, 2019). Jovic et al. (2020) indicate that the critical challenges of RL are related to the customer's negative perception, the high costs associated with reverse logistics, the uncertainties regarding product returns, and the lack of cooperation between supply chain partners in RL. This study attempts to incorporate the principles of RL available in the literature to determine the impact of technology on the RL of blood products.

The demand for public healthcare across developing countries has been increasing over time, and the demand is further increased by the acknowledgement of the need for universal health coverage (UHC) since the implementation of the United Nations (UN) Sustainable Development Goals (SDG) (United Nations, 2020). The UN (2020) estimates that 50% of the world's population does not have access to essential healthcare services, and 100 million people are driven into poverty each year trying to access adequate healthcare services. The World Health Organization (WHO), in alignment with the Sustainable Development Goal (SDG) Target 3.8, strives to attain universal health coverage. This holistic approach encompasses the provision of financial risk protection, access to high-quality essential healthcare services, and the availability of safe, effective, high-quality, and economically accessible essential medicines and vaccines for all individuals. As delineated by the United Nations in 2020, this mission advocates for extending healthcare services to all, ensuring they are accessible without imposing financial hardships. However, this laudable goal has increased demand and subsequently led to constraints and shortages in the provision of healthcare services.

Modern treatment regimens for many malignant diseases and complex surgical procedures would only be possible with the availability of blood (WHO, 2002). Patients requiring red blood cells represent 96% of all requests for blood and blood products, with increased demand for medical treatment, intensive care unit (ICU), general surgery, trauma, gynaecology, and obstetric applications. In comparison, 4% require only plasma and platelets (SANBS, 2019). Proper management of blood and blood products is paramount to improving blood availability. The exorbitantly high cost of blood and blood products for delivering healthcare services is not

sustainable for public healthcare. South Africa (SA) is estimated to spend, on average, between 8.5 and 8.9% of its gross domestic product (GDP) on health, and the supply of blood and blood products amounts to 2% of the public healthcare allocation of GDP (National Department of Health, 2021). The National Blood Authority of Australia concluded that 60% of the blood issued in Australian hospitals could not be recorded (National Blood Authority Australia, 2013). One reason cited was the predominantly paper-based method of requesting blood. The SANBS has painted the same scenario for blood sent to facilities operated by the Gauteng Department of Health (SANBS, 2014a, 2015, 2020, 2021, n.d.; SANBS, 2021). This study seeks to address these concerns using the literature on RL to establish key drivers and barriers.

Introducing technology in supply chain management has accelerated access to information, improving collaboration and integration (Morgan, Richey & Autry, 2016). An increasing number of research studies have supported this to assess the impact of technology on creating RL competency (Morgan, Richey & Autry, 2016). In e-health (Govindan & Bouzon, 2018), technology has provided expertise, enabled research collaboration, and improved approaches to treating disease and illness, both in diagnosis and prognosis. Technology has also provided access to more information (Holland & Bardoel, 2016), improving patient knowledge of basic medical terminology, self-diagnosis, and where/how to acquire notification when necessary. Technology has also accelerated the advancement of medical procedures and diagnostic systems, such as Picture Archiving and Communication Systems (PACS), to perform computerised tomography (CT), magnetic resonance imaging (MRI), and mammograms for the early detection of breast cancer, which are used in trauma cases and other emergency medical procedures.

Using blood and blood products is a recurrent practice in the provision of patient care (SANBS, 2019), and the increase in the number of new hospitals in South Africa expands the demand for blood products in public healthcare (Gordon & Catalini, 2018).

1.1 Problem Statement

The SANBS collects an average of 900,000 blood units annually from just 1% of the SA population that actively donates blood (SANBS, 2021). The blood units provide the SANBS with a stock holding of 4.4 days of blood supply, and each unit has a shelf life of 42 days from the collection day (SANBS, 2021). The collection means that only 500,000 people from the estimated population of 57.7 million SA (Statistics SA, 2020; Statistics SA, 2018) donate blood. However, SA has a 13.1% prevalence of HIV, further restricting potential blood donors (Statistics SA, 2020). The country also has a high prevalence of tuberculosis (TB), increasing the risk and cost of blood collection, resulting in additional restrictions (Meyer et al., 2017). SANBS estimates that up to 40% of the blood and blood products requested by Gauteng health services are wasted annually, making it the top province with the highest volume of blood and blood products wasted annually, driving the cost of blood and blood products very high. The view might also be linked to poor oversight caused by manual logistics processes of blood products. **Figure 1** provides a graphical representation of blood product waste with known reasons for discarding unused (waste) blood products.

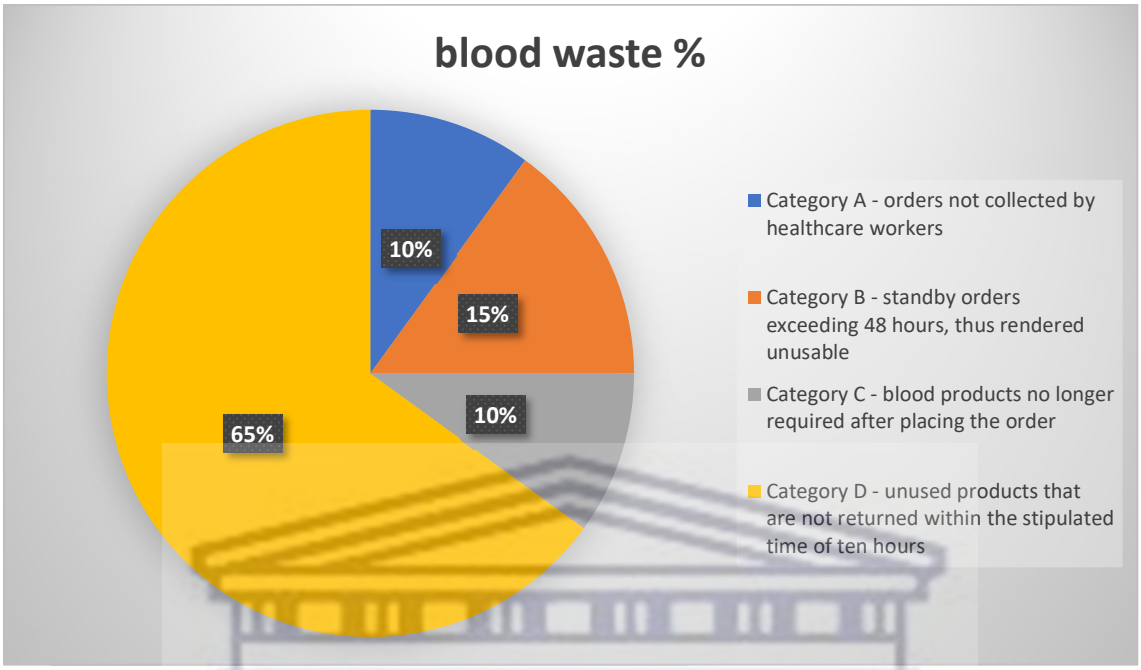

Figure 1: Blood waste by percentage (%) and reason

The reasons for the disposal of blood products are categorically outlined as A, B, C, and D. Predominantly, the significant proportion of blood wastage, constituting 65%, can be attributed to products remaining unused beyond the prescribed timeframe, as delineated in category D. Subsequently, 15% of the wastage stems from products remaining unused due to standby orders exceeding 48 hours, as expounded in category B. Categories A and C, representing orders are placed but not collected and orders no longer required. Respectively, these two categories are responsible for 10% of blood waste each (SANBS, 2019). Due to this waste, 30% of surgical procedures in South Africa? are estimated to be cancelled or postponed daily (SANBS, 2021), risking patients' lives. The uncertainty of availability of blood could also be attributed to poor monitoring of blood ordering processes and lack of technology to support the electronic capture of vital information required in compliance with the Blood Safety and Quality Regulations (2005), National Health Act (No. 61 of 2003), and the WHO's Clinical Use of Blood (2002).

This study focuses on category D in Figure 1, the reason for most blood waste, whereby unused blood products are not returned to the blood bank within ten hours. This study attempts to understand patient blood management (PBM), map the current blood process (forward and reverse), establish critical barriers and drivers in the blood process, and identify challenges in returning unused blood products to the blood bank (reverse logistics of blood products) to reduce waste and cost associated with blood products.

1.2 Research Objectives

The study explores the impact of technology on the reverse logistics of blood in PHF, focusing on category D – unused blood products that are not returned within the stipulated time of ten hours (see **Figure 1**). Key research activities to respond to the above phenomenon are:

a) Mapping the reverse logistics process of blood from PHFs to on-site blood banks (managed by SANBS),
b) Understanding the barriers in the reverse logistics process of blood from PHFs to blood banks,
c) Understanding the drivers attributed to the waste of blood products and
d) Recommending a technological solution to be implemented in PHFs for patient blood management.

1.3 Scope of research and limitations

1.3.1 Scope of research

Akanle, Ademuson & Shittu (2020) state that scoping research makes research manageable, researchable, optimal and SMART (Specific, Measurable, Achievable, Relevant and Time-Bound). The scope must help clarify the study, the extent of coverage, and the time frame (Simon & Goes, 2012). The scoping of the study was done in the early stage of the research cycle to make the research process seamless and focus on the critical areas of the study. The research covered the following areas: a) research questions, b) objectives, c) population, and d) study area. To address the research objectives and scope of the study, the impact of technology on reverse logistics of blood in public healthcare facilities, using the case of the Gauteng Department of Health (GDoH), was the point of interest for the study. The outcome impacts both the forward and reverse logistics of blood products. Due to the study being a mini-thesis, a quantitative approach was ideal. Primary data was collected following the electronic questionnaire survey and the observation method. In contrast, secondary data was collected from SANBS and public health facilities, and operational reports were generated between January 2020 and January 2021.

1.3.2 Limitations

Simon & Goes (2012) state that research limitations are beyond the researcher's control and affect the result of the research. The study encountered several limitations, as follows. Firstly, the collection of records required for the study was not standardised, resulting in different data-cleaning processes for each hospital. The finding was expected since the selected hospitals rendered different levels of care, and various data-cleaning tools and techniques were required. Still, the data output (after cleaning and processing) was subjected to similar analysis for all hospitals. As a result of COVID-19, data collection was also constrained due to official restrictions on the time spent in each hospital. Unfortunately, amid a pandemic, this could not be mitigated due to the necessary timing of the data collection, as the choice of environment for the study required hospital visits. Thus, the time the researcher spent in the research environment and verifying the collected data was limited. The methodology and design of the study used an observation protocol and electronic questionnaire to collect primary data, and for both approaches, time was a limiting factor. It was also noted that nursing personnel performed different tasks despite working in the same ward. The interpretation of the research findings cannot be general and uniformly applicable in each hospital. Future studies must focus on the specific level of healthcare to address the methodology challenges experienced during this research. Conducting the survey after the COVID-19 pandemic might improve data collection and allow more extended interaction with nurses and doctors. Increased time spent in the environment would also be possible, giving sufficient time to interrogate and verify the data quality before analysis.

The sampled participants were health workers. There was no better time to interact with them due to the shortage of staff created by the pandemic, resulting in fewer participants during the observation protocol than

hoped. As a result, the information received from nurses contradicted doctors' statements. Making it important to understand the chain of command to order blood products. And a need to understand the level of accuracy and quality of the information collected on blood transfusion.

During the research proposal preparation, the study was not intended to touch on medical-related findings or discussions. During the data collection stage of the research, however, in addition to the limitations, it was found that some of the challenges and barriers that result in the waste of blood required medical intervention, such as using Hb level to decide whether or not blood transfusion was required. Impacting the intention of the final recommendations to focus only on technology and logistics. Future research studies can use these results to assess further the clinical impact and interventions needed for better management of blood products and reduction of waste.

Finally, the study focused only on public healthcare hospitals, which became a limitation as it was found that blood management processes to manage and prevent the waste of blood in the private health sector were conducted differently. If the scope of the research had covered the private health sector, it would have allowed a direct comparison of public and private processes to assess efficiency and effectiveness. Future studies are recommended for this.

1.4 Significance of the study

This study identifies barriers and factors that affect the RL process of blood products in GDoH PHF, which results in a shortage and waste of blood. By identifying and reporting on these barriers and factors, One potential benefit of GDoH is that it can help manage blood products, thereby reducing the costs associated with blood waste, lowering mortality rates, reducing hospital stays, improving bed availability, and better monitor PBM. The study helps by identifying basic RL principles and their application in healthcare. It attempts to demonstrate, using an empirical method, that technology has a cost-benefit impact on the RL process of blood. This benefit will be realised over time and, if significant, can be redirected to other needs to improve the quality of patient care. The PBM process can be digitized and automated, providing instant information, improved analysis, IoT opportunities, and data-driven decision-making for GDoH.

The study is designed as follows. Chapter one provides background and introduces the research topic, chapter two presents a literature review, chapter three focuses on the research methodology, chapter four presents data analysis and interpretation, Chapter Five focuses on ethical considerations, Chapter Six offers recommendations, and Chapter Seven presents the conclusion.

2. Literature Review

2.1 Reverse logistics

The early introduction of government agencies and regulation enforcement pushed companies across the first world and developed countries into a supply chain field focused on green supply chains, green logistics, and RL (Kumar et al., 2017; Wang, Wang & Chan, 2021). The term RL dates from the nineteenth century, about the closed-loop supply chain (CLSC) and is extensively used in research in multiple industries such as manufacturing, retail, transport, recycling, and waste management (Govindan & Soleimani, 2017; Ritola, Krikke & Caniëls, 2020). Ritola et al. (2020) define CLSC as any activity (design, control, and operation of systems) throughout the life cycle that seeks to maximise value creation. Initial research and focus among scholars and industries has been on incorporating RL into supply chain sustainability and circular economy (Kumar et al., 2017; Chileshe et al., 2018). Several investigations focused on critical barriers to RL implementation (Ali et al., 2018; Pramono, Ulkhaq & Aulia, 2021), while others concentrate on vehicle routing as the crucial driver of managing and coordinating RL activities, waste reduction in production and improving profits (Kumar et al., 2017).

The early 1990s definition of RL has focused on green logistics (environment) and recycling (de Brito & Dekker, 2002, cited in Stock, 1992), and the linkage of RL to environment and recycling also appears in newly conducted studies on RL (Morgan, Richey & Autry, 2016; Chileshe et al., 2018; Wang, Wang & Chan, 2021). García-Sánchez et al. (2019) claim that most RL studies have focused mainly on RL planning activities and problems within RL processes. Although there is an overlap between the description of green logistics and RL logistics (Jovic et al., 2020), the two cannot be used interchangeably. Jovic et al. (2020) have focused on the return of products, and aftermarket green logistics have focused on the impact of air emissions on the environment.

Diversity in RL definitions is well recognised in research and practice (de Brito & Dekker, 2002; Dekker, 2012). The American Reverse Logistics Executive Council defines RL as a process that involves planning, implementing and controlling the flow of material (efficient and cost-effective) from the point of consumption to the point of origin to generate value or incineration (Govindan & Soleimani, 2017). The focus has been on the movement of goods in the opposite direction (consumer to manufacturer), from recycling to recovery (Murphy, 1986; Murphy & Poist, 1989; Stock, 1992; Rogers & Tibben-Lembke, 1999; Dekker, 2011; Chileshe et al., 2018). RL is the only recent addition to the supply chain (SC) reference model referred to by Dekker et al. (2012) and Chileshe et al. (2018). The growing interest in RL is attributed to the economic benefits of the value created by returning used products, legislative compliance due to the emerging green supply chain, and corporate social responsibility (CSR). Pramono, Ulkhaq & Aulia (2021) identify 13 barriers to an efficient organisation's RL process and implementation. The study concludes that RL's top three barriers are the need for an environmental management system, firm policies, and government support. The study indicates that information systems (IS) and technology are critical in creating RL competency. However, there is no direct IT impact on RL activities. Instead, the IT system can impact the surrounding process competencies of collaboration and integration (Morgan, Richey & Autry, 2016). Morgan et al. (2016) concluded that there is a marginal positive relationship between collaboration and RL competency. Availability and sharing of information can result in better processing of returned products. Jovic et al. (2020) separated the challenges of RL from the negative perception of

customers returning products, the high costs associated with RL, the uncertainties about product returns, and the lack of cooperation between supply chain partners in RL.

In contrast, in this study, the researcher seeks to show that adequately implementing RL competency in blood products will result in cost savings, and collaboration between key role players (physicians, SANBS, and administrators) will positively impact RL competency in blood management. This competency has been shown to depend on a high degree of information sharing and technology (Morgan, Richey & Autry, 2016). The impact of technology on the RL of blood products is evaluated through the lens of? These competencies of collaboration and integration.

SCL concepts, such as procurement, distribution, and inventory management, were introduced across first-world countries such as the United States (US) and others in the 1980s to handle blood supply (Schneider, 2013). The concept of SCL brought a systems approach to understanding and managing activities related to the movement and flow of products (in this case, products mean blood and blood products) and services (Hugo, 2018). The systems approach provided a framework to respond to business requirements that otherwise would conflict with each other. Hugo (2018) states that SC is the coordinated movement of products or services with an intended outcome. Introducing SCL into healthcare care has made it possible to track blood products between hospitals and blood banks. With the technology in SCL, it became possible to understand the impact of blood products on patient care through data collected using technology systems such as enterprise resource planning (ERP), electronic data exchange (EDI), and radio frequency identification (RFID) sensors installed in packaging, such as blood returnable basis (BRB) and data analytics (National Blood Authority Australia, 2013).

2.1.1 Economic benefit

An organization will engage in RL if there is potential economic benefit from marketing, competition, and strategic benefits (Dekker, 2012). The resulting economic benefits of RL are realised through direct gain in the form of input material, cost reduction, and recovery of value added. For the management of blood products, a direct economic benefit will include reducing costs and recovering the value added by providing blood services (SANBS, 2015).

2.1.2 Legislative requirements

Dekker (2011) states that legislative requirements refer to any regulation showing that an organisation must recover its product after end-of-life. Unused blood must be returned to SANBS or disposed of following an approved procedure for medical waste disposal (National Health Act, 2003 and Waste Management Act, 2008). The legislative requirements in RL provide a regulatory framework that allows the recovery and disposal of blood products, a mandatory requirement for healthcare facilities (SANBS, 2015). Failure to adhere to the regulation will result in penalties against the provincial department or municipality in the case of public healthcare or hospital in the case of private healthcare (Marik, 2015; Pierskalla, 2005; SANBS, n.d.; WHO, 2002). Distribution of blood and blood products is neither a profitable avenue nor a 'calling/feeling' but a legislative requirement prescribed in the South African Constitution (No. 108 of 1996) and is regulated by the National Health Act (No. 61 of 2003) and the Human Tissue Act (No. 65 of 1983).

2.1.3 Corporate Social Responsibility

Corporate Social Responsibility (CSR) is described as a concept to measure corporate citizenship in organisations (Hejazi & Nasiri, 2014) or a set of values or principles that require an organisation to participate in RL (Dekker, 2012) actively. Institutions such as the SANBS have a responsibility to prioritise social (community participation in blood donation) and environmental (disposal of health waste and human tissue) issues, as stipulated in the South African Constitution (No. 108 of 1996) and regulated by the National Health Act (No. 61 of 2003) and Human Tissue Act (No. 65 of 1983).

2.1.4 Reverse logistics process flow

Blood products are said to return to their original distributor because they are no longer required, the patient died, or there was an incorrect cross-match or double ordering (SANBS, n.d.). SANBS (2015) states that blood can be returned to the blood bank if the stipulated conditions are met. Of the 480,000 units of blood ordered between January and December 2020, it is estimated that less than 7% was returned to the blood bank (SANBS, 2021), increasing the 'blood bill' by an estimated R900 for each cross-match. Players in the RL process of blood and blood products include doctors, nurses, ward clerks, and phlebotomists, all involved in the forward and reverse logistics of blood products (SANBS, 2015).

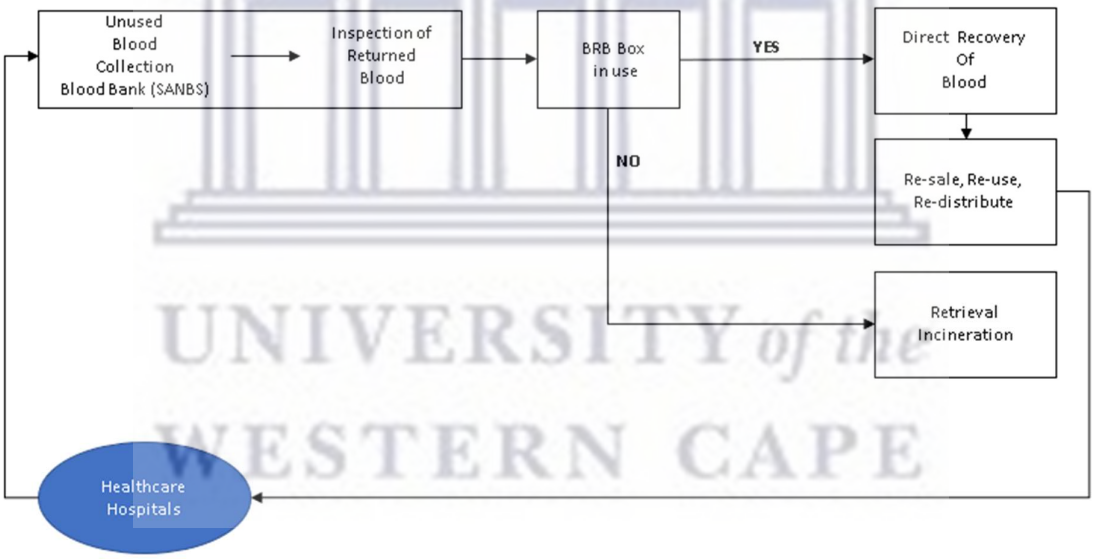

Figure 2: Reverse logistics general process (Dekker, 2011) adjusted for blood process

Figure 2 shows a high-level view of a general reverse logistics process adjusted for blood products. Unused blood is collected from healthcare hospitals to the nearest blood bank. The collected blood units are inspected, where direct recovery is the process by which blood is recovered within the stipulated conditions (WHO, 2002; SANBS, 2014a, 2015, 2019) and can be redistributed without processing, provided a BRB system is used. The BRB box is a vital component that allows the blood bank to accept blood from facilities. The collection is carried out by hospital 'runners', and the sealed BRB box is delivered to the blood bank for redistribution and reuse (SANBS, 2015). Where a BRB box was never used, the collected blood was retrieved and incinerated.

2.2 Public health care

Access to public healthcare is enshrined in the Republic of South Africa constitution, supported by legislative prescripts (Republic of South African Government, 1996; National Department of Health, 2003). SA has an estimated population of 57.7 million, and Gauteng province (GP), with a population of 14.6 million, is reported (Statistics South Africa, 2020). 84% of the 55.5 million SA population is estimated to depend on public healthcare, while 16% use private healthcare (Maphumulo & Bhengu, 2019). Maphumulo & Bhengu (2019) indicate a correlation between the influx of people to cities and the demand for healthcare services, which means that the higher the population in the city, the greater the need for healthcare services. The GP's public health system records about 26.6 million patient visits to the outpatient department (OPD) and primary healthcare (PHC) service platforms and 905,000 patients in the emergency department each year (Gauteng Department of Health, 2019). Between January 2020 and January 2021, GDoH healthcare saw 349,000 trauma cases and 70,000 obstetric deliveries by caesarean section (University of Oslo, 2021). Obstetric bleeding significantly contributes to obstetric morbidity and mortality among women of childbearing age, while early blood transfusion increases the chances of survival among trauma patients (Bloch et al., 2018). GP healthcare services consumed an average of 480,000 blood units, with a value of R756 million between January and December 2020, representing 50% of the total blood collection of SANBS in the same period (SANBS 2021).

GDoH has developed standard operating procedures (SOPs) for handling the return of blood products, in line with the legal requirements stipulated in the National Health Act 61 of 2003, WHO, SANBS and the clinical guidelines edition 5 of 2014 and other related regulations. The scope of the SOPs is limited to a gatekeeping function to monitor compliance when products are ordered. This function covers the physician who orders the blood product, the patient's details, the International Classification of Diseases (ICD) 10 codes, and the haemoglobin trigger (SANBS, 2014). The traceability of all blood products is a legal requirement (National Department of Health, 2003).

2.3 Blood transfusion

Blood transfusion is integral to therapy for many common and severe diseases (SANBS, 2014; WHO, 2002). Without the availability of blood, modern treatment regimens for many malignant diseases and complex surgical procedures would not be possible (SANBS, 2014a). SANBS (2015) emphasizes the importance of collecting enough blood to maintain blood stock to cover 5 to 10 days. This is to ensure high blood product availability. However, with the increasing demand for medical, ICU, general surgery, trauma, gynaecology, and obstetric applications, 96% of all patient blood requests are for red blood cells, while 4% require plasma and platelets (SANBS, 2019). The use of blood transfusion to deliver clinical care is an evidence-based process guided by legislative prescripts and guidelines (WHO, 2002; Association for the Advancement of Blood & Biotherapies, 2010, 2012). These are essential components of medical practice and are critical in allowing treatment in medical disciplines such as haematology and oncology (Dzik et al., 2011). **Figure 3** shows a high-level forward process used in GDoH hospitals for blood transfusion, as provided by the Clinical Guidelines for the Use of Blood Products in South Africa (GDoH, 2018). There is a failure in the process in that it does not provide a holistic view from end to end, leaving a critical gap in the life cycle of the blood process.

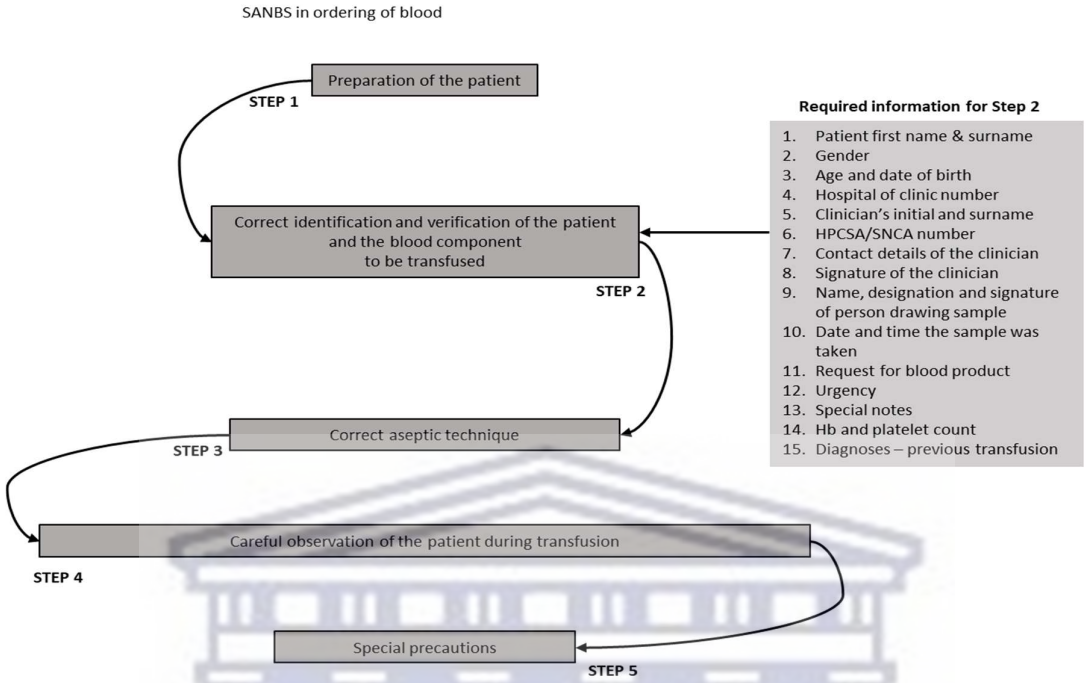

Figure 3: Graphical representation of the procedure of the Clinical Guidelines for the Use of Blood Products in South Africa (GDoH, 2018)

SA has made significant strides in making blood and blood products available in public healthcare (SANBS, 2014a). However, Mangwana et al., (2017) indicate that the impact of HIV/AIDS, tuberculosis and hepatitis B-related diseases is a risk to the safety of the blood supply. Such a risk and the potential for blood wastage (Mangwana et al., 2017) make blood and blood products scarce. For this study, blood wastage is any blood or blood product returned to the blood bank after the specified 12-hour cycle without being used (GDoH, 2018). Circular letter 02 of 2018 and the SANBS guidelines (2015) utilised at the GDoH hospitals provide a provision that blood ordered using the BRB system can be returned, provided that the seal of the BRB compartment is intact, the cold chain is maintained. The BRB box is returned to the blood bank within 12 hours. SANBS and Circular 2 of GDoH provide guidelines on parameters for the use of the BRB box. During this research period, the BRB box is only mandatory for requests related to or associated with elective surgical procedures (SANBS, 2015). Parameters are defined to contain the costs associated with using BRB boxes. However, healthcare workers prefer to use something other than the BRB box system, fearing its increased costs (SANBS, 2019). Legislative prescripts are silent on blood wastage (WHO, 2002; National Department of Health, 2003; Association for the Advancement of Blood & Biotherapies, 2010, 2012). As a result, the focus has been on adverse events related to blood reaction cases and patient concerns. This leads to poor accountability in the traceability of blood, leading to hight waste and a shortage. Multiple studies (Franchini et al., 2019; Guðbjörnsdóttir, 2015; Mangwana et al., 2017; Marik, 2015; Pierskalla, 2005; SANBS, n.d.; Thomson et al., 2019; WHO, 2002) have shown that, shortage blood and blood products in a hospital setup is the highest cause deaths of most patients in trauma, accident and emergency, obstetrics and gynaecology, etc. leading to poor personal liability for healthcare professionals (SANBS, 2014; WHO, 2002).

PBM is a system that aims to manage the movement of blood products between consumers (hospitals) and suppliers (SANBS, 2014b). The PBM system reduces mortality, reduces ICU admissions, and improves patient outcomes. Understanding blood usage, the 'blood bill' and 'return waste' is necessary to obtain patient benefit and drive the appropriate use of blood and blood products (SANBS, 2015).

2.4 Reverse Logistics Framework

The study adopts a simplified conceptual framework for RL, focusing on why there is a reverse flow of products (return reasons and driving forces). **Figure 4** is a conceptual framework adapted from du Toit & Vlok (2014) that aligns the Healthcare Organizational Strategy (OS) and the RL strategy for blood products. OS in healthcare is the direction and scope of an organisation over a predetermined period with benefits to the organisation, which plays a vital role in business performance (improved patient outcome, reduced mortality, reduced hospital stay, and effective PBM) (Fadeyi et al., 2015). Healthcare care strategies are developed to plan for any problems or challenges that could impact the delivery of healthcare services (American Society of Clinical Oncology (ASCO), 2009). OS helps healthcare facilities to be proactive and agile in adapting to environmental changes, such as an increase in healthcare demand amid scarce resources (Fadeyi et al., 2015). It combines the health department's vision, goals, plans, and actions. Weeks (2011) indicates that the main objective of the RL strategy is to optimise the movement of goods between consumers and manufacturers. The principle drives the logistics of blood between SANBS and hospitals. Implementing healthcare strategies for blood management through PBM (du Toit & Vlok, 2014). Implementing OS is required to coordinate procedures, financial plans, and programs that help the strategy become an action for proper execution (Fadeyi et al., 2015).

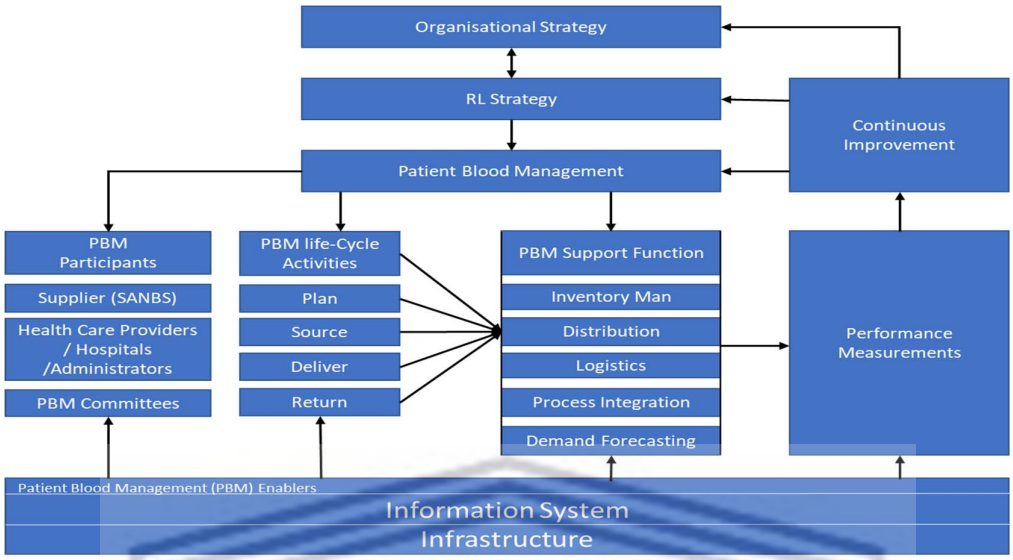

Figure 4: Conceptual framework (adapted from du Toit & Vlok, 2014)

The PBM comprises participants, lifecycle activities, and support functions. As key organisational resources and role players, PBM participants are linked to the overall blood management life-cycle process. Organisational value is created when business input (resources) interacts with business activities (Association of International Certified Professional Accountants, 2020; Harmon, 2011; Piboonrungroj et al., 2017). With blood management, PBM participants create value when clinical results show improved patient outcomes, reduced patient mortality, reduced blood wastage, and lower costs associated with transfusions. There is a many-to-many relationship between lifecycle activities and support functions. Performance measurement acts as a feedback loop for continuous improvement, which affects RL strategy and management, while PBM enablers act across functions, activities, and participants. This portfolio approach to strategic decision-making considers all business activities to create maximum value (Corporate Finance Institute, 2015).

The OS manages an organisation's resources, risk, and return. Healthcare services strategies are developed to plan for any problems or challenges that might impact the delivery of health services (ASCO, 2009). The RL strategy can be defined as establishing how RL activities in an organisation should be designed and operated to produce the highest value (Fadeyi et al., 2015). The management of blood and blood products impacts the overall health system. PBM implements the above strategies and links the RL strategies to the components of PBM (participants, life-cycle activities, and support functions) to mitigate the impact (du Toit & Vlok, 2014).

2.4.1 Participants

Fadeyi et al. (2015) indicate that participants are units or entities involved in SC. Participants (internal and external stakeholders) in PBM are healthcare providers, SANBS, administrators, patients, PBM Committees, and hospitals. Participants are classified according to their roles and responsibilities in PBM. According to the Rural Health Advocacy Project (2021), Allied Health Professions Act 63 of 1982, Health Professions Act 56 of 1974, Nursing Act 50 of 1978, Pharmacy Act 53 of 1974, and Dental Technicians Act 19 of 1979, PBM participants are doctors, nurses, dentists, pharmacists and medical specialists, SANBS as the supplier of blood and blood

products, patients as any receiver of health care services, hospitals as health establishments classified as a hospital by the Minister in terms of Section 35 of the National Health Act (No. 61 of 2003), PBM Committees as oversight committees for blood and blood products, and administrators.

2.4.2 Lifecycle Activities

The activities of the PBM life cycle impact the life cycle of blood products (Fadeyi et al., 2015), and in the proposed framework, the activities are categorised according to the Supply Chain Operations Reference (SCOR) model: plan, source, make, deliver, and return (Soyka, 2013). These elements are described by Soyka (2013) as follows: to plan is 'a process that balances aggregate demand and supply of blood products to develop a course of action that best meets established business rules'; to source is 'a process that procures goods and services (blood products and adjacent resources) to meet planned or actual demand'; to make is 'a process that transforms goods into clinical interventions to meet planned or real demand'; to deliver involves 'processes that provide finished goods and services to meet planned or actual demand'; and to return is a process associated with the return of unused blood products or receiving returned products for any reason. These activities are carried out throughout the life cycle of the process and are supported by PBM support functions. This section discusses the visibility of blood requests, preparation, collection, and return to relevant support.

2.4.3 Support Functions

Control and support of PBM activities are achieved through support functions. These include inventory management, distribution, logistics, process integration, and demand forecasting. Functions support PBM activities by monitoring blood stock levels to ensure a hospital does not run low on blood stock and thus avoid a higher risk of mortality due to insufficient blood availability. The collection and returning of unused blood ensure adherence in handling biomedical material. Collected blood products must be used within the stipulated window period; however, if the product does not reach the patient's vein, it must be returned to the blood bank within 12 hours from collection for reuse and incineration. The critical driver of support functions is trust between organisational units that allow them to follow prescribed business processes, understand each other, communicate challenges and bottlenecks, and have a common organisational goal (Fadeyi et al., 2015).

2.4.4 Performance Measurements and Continuous Improvement

Performance measurements affect all levels of planning and control (Fadeyi et al., 2015). There are two aspects of a performance measure: the past and present process under consideration and the set performance goals (Karabiyik, 2009). SANBS (2015) states that to benefit patients and drive the use of blood and blood products, understanding how much is used (usage/'blood bill') or returned (wastage) cannot be the only focus when analysing statistics. The tracking and monitoring factors that affect practices contributing to patient outcomes and costs associated with transfusions must be measurable and quantified (SANBS, 2015). The performance measure in the proposed framework is part of the feedback loop that links the PBM support functions. The effectiveness of any continuous improvement process depends on the support functions (Urbaniak, 2015). Continuous improvement in the proposed framework links performance measurement and the RL strategy.

2.4.5 Patient blood management enablers

The PBM activities, the support functions, and the performance measures are all affected by elements that determine their performance (Fadeyi et al., 2015). These elements are called enablers, and the information

system and infrastructure will be the focus of this study. Any supply chain process's efficiency depends on the information flow (Fadeyi et al., 2015). The principle reduces costs and increases customer satisfaction (Kumar et al., 2017). The traceability of all blood products is a legal requirement in SA (National Department of Health, 2003). The efficient movement of blood is always discussed with the availability of infrastructure. The conversation takes a technological perspective and the need for physical access to blood banks (South African National Blood Services, 2015).

2.5 Impact of technology on blood products

Studies in healthcare by Bigus et al. (2011); Kumar (2011b); Reis, Visser & Frankel (2013); Mostashari (2014); Sacchini et al. (2021); Delgado (2022); and Mukherjee & Walley (2022) have indicated that technology can solve complex problems in healthcare that were previously thought to be too intractable. They can do this by 1) providing timely and detailed information to multiple medical specialities; 2) enabling the delivery of care across multiple healthcare specialities and levels of care; 3) enabling tracking of patients with known comorbidities; 4) detecting and recording adverse events related to drug reactions; 5) providing epidemiology data to track the spread of epidemics and 6) helping to provide best treatment alternatives for communicable diseases. Technology has changed traditional logistics and supply chains to achieve benefits such as increased organisational effectiveness and efficiency (Gunasekaran, Subramanian & Papadopoulos, 2017). Chaudhari (2019) suggests that the efficiency of technology in logistics is measured by the amount of value added and the competitiveness created in the organisation. Success in creating this value depends on selecting the right technology for the application, the availability of organisational infrastructure, culture, and management policies (Chaudhari, 2019). Gunasekaran, Subramanian and Papadopoulos (2017) confirm that technology has been shown to some extent to improve the speed of product identification, data collection, processing, analysis, and transmission while maintaining a high level of logistic accuracy. Jovic et al. (2020) concluded that the blockchain could reduce the over-ordering and under-ordering of products, track and verify returns against original transactions, and minimise costs. The latter is a known phenomenon in the order process of blood products. However, according to Soysal et al. (2015), product waste is inevitable when the demand is unknown. These are critical products such as blood and perishable products. This study and other published literature mentioned above confirm that over-ordering products such as blood and the associated high costs are predominant challenges healthcare facilities face.

At a high level, the top three drivers of blood product waste are 1) the state of blood during transit, 2) packaging, and 3) communication between hospitals and the SANBS (SANBS, 2014, 2015, 2020). The use of technology has been known to improve the transportation and packaging of fragile and perishable goods by providing real-time information on the conditions of the product during transit. Process automation using technology might assist with creating a single communication portal for nurses and doctors. Process automation can be achieved by implementing health information systems to order blood products.

The WHO adopted a Global Strategy on Digital Health (GSDH) in 2020 to provide a platform for innovation and digital health to improve health outcomes. The key objectives of the GSDH are a) 'Translating the latest data, research, and evidence into action', b) 'Enhancing knowledge through scientific communities of practice', and c) 'Systematically assessing and linking country needs with innovation supply' (WHO, 2002). Based on the WHO

GSDH above and other literature, enough empirical evidence supports the idea that introducing technological innovations can improve health outcomes. Using technology to enhance the quality of products, reduce cost, and technical readiness level (TRL) is a well-studied area (Gunasekaran, Subramanian & Papadopoulos, 2017; Winkelhaus & Grosse, 2020; Parola, Satta, Buratti & Vitellaro, 2021; Wanner et al., 2021). Nikolii et al. (2015) concluded that the application of Radio-frequency identification (RFID) in the logistics field had been associated with a 26% reduction in processing costs and improved business efficiency through automation and digitisation of processes. Winkelhaus and Grosse (2020) demonstrate that more than 17 billion devices have already been connected via the IoT, and the amount is expected to reach 30 billion devices in 2020.

WHO (2002) states that Poor data collection processes and data quality lead to poor health outcomes and further emphasizes the importance of accurate collection of information about the demographics of patients (full names, date of birth, hospital number, date of sample withdrawal, and identification of the ward). Tokosi (2016) indicates that this leads to better and more accurate delivery of healthcare services, including safe blood transfusions. Accurate collection of demographic information from patients has been associated with efficient blood product breakdown management and accurate cross-matching between patient and blood type (SNABS, 2019).

Jovi et al. (2020) argue that RL has been found to increase the cost of redistribution in manufacturing, slow production growth, and competitiveness. Álvarez López et al. (2018), writing on RFID Technology for Management and Tracking: e-Health Applications, state that using IoT technology such as RFID can reduce the risk of medical errors in hospitals and improve drug management. Wanner et al. (2021) further develop a five (5) step process for performing technology assessments: 1) development of an assessment framework to provide the background of the subject and technology background; 2) secondary research to zoom in on the background, identify risk for implementing technology and required infrastructure; 3) thesis and preliminary measures to present the summary of the secondary research 4) expert interviews and detailed measures to provide an as-is analysis and process mapping and process explanation; and 5) review and publication of the results to provide a summary of the entire process and overview. However, the study does not acknowledge the need for automation during the digitisation transformation. (Parola et al., 2021) state that ICT systems and digital technologies generate valuable business opportunities and cost savings in various logistics activities, including cargo handling, warehouse management, track and trace operations, sales activities, safety and security, and payment methods. Based on the above considerations, many scholars recognize the beneficial effects of digital technologies on logistics centres' business models and strategies (see, e.g., Carlan et al., 2017; Cariou, 2018; Gavalas, Syriopoulos & Roumpis, 2022; Jović et al., 2022).

The absence of technology limits the availability of information for management to make data-driven decisions (Gunasekaran et al., 2017) and the correct information being delivered to the right place at the right time (Winkelhaus & Grosse, 2020). This information is relevant in providing clinical care to sick patients and blood management (Clinical Guidelines for using blood products in South Africa, 2014). The availability of information in PBM will require automation and digitisation of the blood management process. According to Chaudhari (2019), the use of technology in logistics can be segregated into three categories: 1) Automatic Identification Technology (AIT), 2) Communication Technology (CT), and 3) Information Technology (IT). BRB boxes can be

tracked between healthcare facilities and blood banks to provide real-time blood conditions in transit, and CT, IT and EDI can be utilised to share information between the entities (Chaudhari, 2019).

Implementing an electronic health record is a mandatory requirement for digital transformation in healthcare, with a health information system (HIS) being the starting point (Ayat & Sharifi, 2016). An HIS is a system used in healthcare facilities to capture patient information (demographics, allergies, next of kin, a diagnosis summary, etc.) to improve healthcare outcomes, quality improvement, and cost reduction while providing healthcare services (Ayat & Sharifi, 2016). An assessment must be performed to establish the maturity level of the health system to enable digital transformation. This study will use the electronic medical record adoption model (EMRAM) initially established in the 70s and later reviewed by the Healthcare Information and Management Systems Society (HIMSS) to establish the maturity level of HIS in the selected facilities (see **Table 1**). EMRAM is a widely-used assessment model, the formulation of which is based on the optimal utilisation of IT and HIS in hospitals (Ayat & Sharifi, 2016).

Table 1: Stages and specifications of the electronic medical record (EMR) adoption model (Ayat & Sharifi, 2016; Ayat, Sharifi & Jahanbakhsh, 2017)

STAGE	EMR Adoption Model Cumulative Capacities
7	Complete EMR: Health Information Exchange (HIE); Data Analytics, Governance, Disaster Recovery, Privacy and Security
6	Technology Enabled Medication, Blood Products, and Human Milk Administration; Risk Reporting
5	Physician documentation using a structured template; Intrusion / Device Protection
4	Computerized Provider Order Entry (CPOE) with Clinical Decision Support (CDS); Nursing and Allied Health Documentation; Basic Business Continuity
3	Nursing and Allied Health Documentation; Electronic Medication Administration Record (eMAR); Role-Based Security
2	Clinical Data Repository (CDR); Internal Interoperability; Basic Security
1	Ancillaries – Laboratory, Pharmacy, and Radiology / Cardiology information systems; Picture Archiving and Communication System (PACS); Digital non-DICOM image management
0	All three ancillaries were not installed.

The assessment model is divided into stages 0-7, 0 being the three ancillaries not installed (everything still in paper-based records), and 7 being complete EMR, external HIE (data analytics, governance, disaster recovery, privacy, and security). For this study, the process of digitisation and automation of blood products requires the facility to be at stage 6 of HIS adoption (technology-enabled medication, **blood products,** human milk administration, risk report). Only a handful of North American and European hospitals have reached the seventh stage, and there are no hospitals in the Middle East at stage 7, and some UAE countries and Saudi Arabia have reached stage 6 (Ayat & Sharifi, 2016).

Hypothetically, technology could solve the challenges of blood transfusion related to the patient information collection, tracking, and visibility of BRB boxes, poor return of unused blood, and high cost of blood services (García-Sánchez, Guerrero-Villegas & Aguilera-Caracuel, 2019).

2.6 Conclusion

The world of medical care has evolved as society gains access to knowledge that leads to changes in the approach to illness and disease, and more research is required to improve the delivery of healthcare services (WHO, 2002). Blood transfusion is integral to therapy for many serious and common diseases (Clinical Guidelines for Using Blood Products in South Africa, 2014). Modern treatment regimens for many malignant diseases and complex surgical procedures would only be possible with blood availability (SANBS, 2015). RL provides a look-back mechanism for forwarding logistics in SC, which is crucial for product recovery and recycling (de Brito & Dekker, 2002). Technology has changed the operational landscape in SC. Organisation value, competitiveness, and efficiency are determined by the degree to which data can be made available for decision-making (Chaudhari, 2019). Including technology in an organisational strategy for blood management will positively impact the resolution of poor organisational performance and reduce operational costs. However, this requires a coordinated collaboration between the organisational strategy, the RL strategy, and blood management (Fadeyi et al., 2015).

3. Research Methodology

3.1 Research design and strategy

Denzin and Lincoln (2017) state that research methodology and strategies are determined by the subject being investigated and the type of research questions. A quantitative applied research approach has been chosen as the methodology for the study. This structured approach uses quantifiable data to articulate facts and attempts to solve specific, practical questions and generalise to a larger population. The study is descriptive in its objective of documenting the factors that impact RL, mapping the current blood process using observation techniques, and providing a technological solution to improve the overall RL process of blood products. A descriptive electronic survey questionnaire and observation techniques were used to collect primary, while operational reports from GDoH hospitals and SANBS were collected as secondary data.

3.2 Population sampling

Public healthcare is divided into four levels of care, using the total number of functional beds available per hospital and the type of services: academic hospitals will have >1,200 beds, tertiary hospitals >1,000 beds, regional hospitals 400-800 beds, and district hospitals 200-800 beds (National Health Act No. 61 of 2003). The sampling frame is based on the level of care in the participating facilities to collect and harmonise the required research data. The participating facilities are Charlotte Maxeke Hospital (academic hospital n = 1), Edenvale Hospital (regional hospital n = 1), Kalafong Hospital (tertiary hospital n = 1) and Kopanong Hospital (district hospital n = 1). Taherdoost (2016) states that using this type of stratified random sampling approach provides a logical representation of the population for the study. The population sample is limited to five doctors from each level of care (n = 20), five nurses from each level of care (n = 20), two blood administrators from each level of care (n = 8), four SCM administrators from each level of care (n = 16), the Head of Department (HoD) in surgery and trauma from each level of care (n = 8), four SANBS blood administrators (n = 4), a SANBS haematologist (n = 1) and one Blood Management Committee (n = 1) from an academic facility. As there is an understanding that each level of care has unique business processes, a separate exploration of each level is warranted.

3.3 Sampling technique

A stratified random sampling procedure was used to select participants in this study. Taherdoost (2016) indicated that stratified sampling divides the population into strata, and a random sample is collected from each subgroup. This technique was chosen to ensure equal representation of each healthcare level (see Section 3.2 for stratification of levels).

Table 2: Population sampling for the study

Category	Sampling Number/ Level of Care	Level of Care and Facility Name	Total
Doctors	5	Charlotte Maxeke Hospital (Academic Hospital), Edenvale Hospital (Regional Hospital), Kalafong Hospital (Tertiary Hospital), and Kopanong Hospital (District Hospital)	20
Nurses	5	Academic, Tertiary, Regional, and District	20
Administrators (GDoH)	2	Academic, Tertiary, Regional, and District	8
Supply Chain Management Administrators	4	Academic, Tertiary, Regional, and District	16
Head of Department (HoD) in surgery and trauma	1	Academic, Tertiary, Regional, and District	4
Administrators (SANBS)	1	Academic, Tertiary, Regional, and District	4
Haematologist	1	SANBS	1
Blood Management Committee	1	Academic	1

The diverse population depicted in **Table 2** has been chosen for the study to cover: 1) the clinical process of ordering blood and requirements (forward and reverse logistics); 2) the administrative process of ordering blood and required information; 3) the supply chain integration processes; and 4) the blood bank process and required information (forward and reverse process). Following Taherdoost (2016), the logic for this sampling is not the proportion of the sampled research population but the sample size relative to the population's complexity.

3.4 Data collection and data collection instrument

Various data collection methods can be used for qualitative and quantitative purposes, the difference being the restriction imposed and the structure (Kumar, 2011a). This study used an observation protocol and an electronic questionnaire to collect primary data. Although secondary data were collected from SANBS and public health facilities, operational reports were generated between January 2020 and January 2021.

The use of observation for data collection is better suited when the study is more interested in behaviour than individuals' perceptions or when subjects such as healthcare personnel are too busy and unavailable to provide objective information about a particular interest (Kumar, 2011a). The observation was ideal for mapping the current process of ordering blood products from the on-site blood bank (SANBS) to the request point (hospital ward, accident and emergency unit, trauma and casualty unit). Using observation for primary data collection provides the researcher with first-hand experience while interacting with participants in context (Creswell & Creswell, 2009) - in this case, in their respective facilities, Charlotte Maxeke Hospital, Edenvale Hospital, Kalafong Hospital, and Kopanong Hospital. The data collected were categorically recorded using the observation protocol developed for the study (see the observation protocol Annexure B). As Kumar (2012) indicates, this is generally

achieved by watching behavioural patterns to obtain information about a particular interest, and the observed process will be recorded as is without overlooking or omitting any steps. Due to the general nature of the environment (hospital ward, accident and emergency unit, trauma and casualty unit), the study followed a non-participant observation approach, as this ensured less interference with the participants in the hospital during working hours. The researcher observed the participants as they ordered blood products for patients needing blood transfusions from the on-site blood bank (SANBS) to the hospital ward, accident and emergency unit, and trauma and casualty unit. A randomised list of observed participants was generated that included five doctors at each level of care (n = 20), five nurses from each level of care (n = 20) and two blood administrators from each level of care (n = 8). Although it was not possible to observe all participants involved, the randomised selection included passive participants, HoD in surgery, and trauma for each level of care (n = 8), four SANBS blood administrators (n = 4), one SANBS haematologist (n = 1) and one Blood Management Committee (n = 1). The randomised participants were recipients of the electronic survey questionnaire. Due to the sensitivity of the environment chosen for the research, no pictures, patient data, or labels were collected or recorded during the observation. Data collected by the observation method of this research study were anonymised from the source, meaning that identifiable information was removed from the data (Vokinger, Stekhoven & Krauthammer, 2020). Questionnaires are very popular among most research studies in information systems and social sciences to obtain relevant information on validity and reliability. In contrast, the precision and consistency of a questionnaire are significant parts of a research methodology (Taherdoost, 2016). An electronic survey questionnaire was an ideal choice, considering the environment in which the study was conducted. Public hospitals are generally known to be busy environments, and interviews requiring more time were not considered feasible due to busy work schedules. The researcher used Microsoft Forms, an online tool to collect data through electronic questionnaires and surveys (Microsoft, 2021), to design, create, and distribute the electronic questionnaire to the randomised participants listed in the previous paragraph. The choice of the tool was based on the ease of use and the ability to anonymise the response and provide a consolidated report for all responses. Several limitations are associated with using a questionnaire and observation in a research study. Kumar (2012) indicates that a low response rate can reduce the study's sample size, which may be due to the length of the questionnaire, the opportunity to clarify issues, poor access to the questionnaire online, and self-selecting bias. Limitations were encountered during the data collection, which resulted in a low response rate. Participants were assisted in taking the survey, resulting in an improved response rate, and the questionnaire was simplified to reduce complexity. The limitations that arise from the use of observation in data collection are that: a) individuals are prone to change their behaviour while being observed (Creswell & Creswell, 2009), and b) interpretation and observer bias can hamper the collection of vital data (Kumar, 2012). To address the observation limitations, the researcher, as an employee of the GDoH at the time of data collection, limited interference during the observation and recorded the observed process. Finally, environmental limitations limited the collection of some information due to the need to respect patient privacy. Personalised information was anonymised, however, and a consent form was used in anticipation of the use of any data necessary for the research study. The researcher was fully aware of the limitations regarding the questionnaire and observation

method for collecting data, and precaution through the researcher's skills was applied to limit any data bias and discrepancy.

3.5 Ethical considerations

According to the Cambridge Dictionary (1995), ethical means 'relating to beliefs about what is morally right and wrong.' Several ethical considerations were taken into account to ensure the research could be conducted appropriately (Babbie & Mouton, 2001). According to Vokinger, Stekhoven and Krauthammer (2020), health information used for a research study may lead to exposure to personalised data, resulting in risks of discrimination. Therefore, to comply with ethical considerations in conducting research, all participants were asked to consent to the questionnaire and participate in the study. As indicated in the previous section, due to the sensitivity of the environment chosen for the research study, no pictures, patient data, or labels were collected or recorded, and the data was anonymised. The approach was to remove identifiable information from the data (Vokinger, Stekhoven & Krauthammer, 2020), and the same was applied to data collected during the observation method of this research. Participants were asked to consent to be observed, and no personal data was collected. At the time of data collection, the researcher worked for the GDoH as Acting Chief Information officer and was therefore tasked with protecting and monitoring the information used to provide healthcare services in multiple facilities, disciplines, and levels of healthcare. In that role, the researcher's responsibility included all ethical considerations, including existing legislative prescripts within information management (Republic of South Africa, 2002, 2013; National Department of Health, 2003; Department of Justice RSA, 2018). The University procedure was followed to obtain proper ethics clearance before starting data collection for the study. The GDoH has a Research Ethics Committee to monitor ethical compliance in the Department Section 9. The appropriate GDoH channel was followed to ensure compliance with the Research Ethics Committee before beginning research work and obtaining the appropriate approval. In conclusion, ethical considerations followed the GDoH Standard Operating Procedure (SOP), and policy and procedures were considered, where applicable.

4. Data Analysis and Interpretation

4.1 Introduction

Four hospitals in Gauteng province were visited as part of the research study, as discussed in the previous section, sampling and selection process of the research method section 3. The primary objective of the visits was to a) understand the barriers in the RL process of blood from PHFs to blood banks, b) map the RL process of blood from PHFs to on-site blood banks, and c) understand the drivers attributed to the waste of blood products. Primary and secondary data were collected, as discussed in section 3 of the research methodology. As discussed in the data collection section, two methods were used to collect primary data: the observation protocol and the electronic questionnaire survey. Secondary data were collected from operational reports, blood management reports, blood usage reports, and blood waste reports used by the GDoH and SANBS, generated between January 2020 and December 2021.

The observation protocol was a non-participant observation protocol that involved a visit to each of the four selected hospitals. Participants in the observation protocol were asked to complete the electronic questionnaire to collect primary data. Data collected from operational reports (secondary data) before visits were used to identify the three main wards with the highest RBC orders. The exercise allowed the researcher to reduce the time needed to collect primary data and mitigate the risks associated with exposure to COVID-19 due to spending extended periods in hospital settings. Secondary data were used to establish a baseline of ordered, received, and transfused blood units. The sampling methodology used a stratified random sampling procedure to select participants and divide the population into strata, with a random sample collected from each sub-group. Using the Microsoft Forms platform, an electronic questionnaire was distributed to health workers in hospital wards who were part of the observation protocol. Participants identified using the stratified random sampling procedure were asked to complete the electronic questionnaire. Initial responses were very few, resulting in a less than 5% response rate. Visits were made to four selected hospitals to encourage participation and assist participants in completing the electronic questionnaire, after which 28 (38%) responses were received.

The secondary data collected comprised 614 thousand rows of data presented in twenty columns. See Chapter 9, description of data labels and formatting on how the data were processed and anonymised to reduce the risk of exposing patients' personal information. Each row provided details of the product description, ward description, reference document, facility description, billing information, invoice quantity, ICD10 code, and total Rand value of the product. The primary data focused on the top three wards in each of the four identified hospitals, as shown in **Table 3**, ordered by the hospital with the highest number of RBCs ordered between January 2020 and December 2021 to that with the lowest number.

Table 3: Total number of RBCs ordered between January 2022 and December 2021

#	Level of Care	Hospital Name	RBC Ordered
1	Tertiary	Kalafong Hospital	7 540
2	Academic	Charlotte Maxeke Hospital	5 374
3	District	Edenvale Hospital	5 221
4	Regional	Kopanong Hospital	2 468
		Total	**20 603**

4.2 Product background and breakdown

According to the research literature, 96% of patients require RBC, while only 4% require plasma and platelet products (SANBS, 2019), which is also reflected in the GDoH and SANBS data, as shown in **Figure 5**. Most of the blood units ordered were RBC (74%), at a cost of R108million, followed by fresh frozen plasma (20%), at a cost of R30million and platelets (6%), at a cost of R33million.

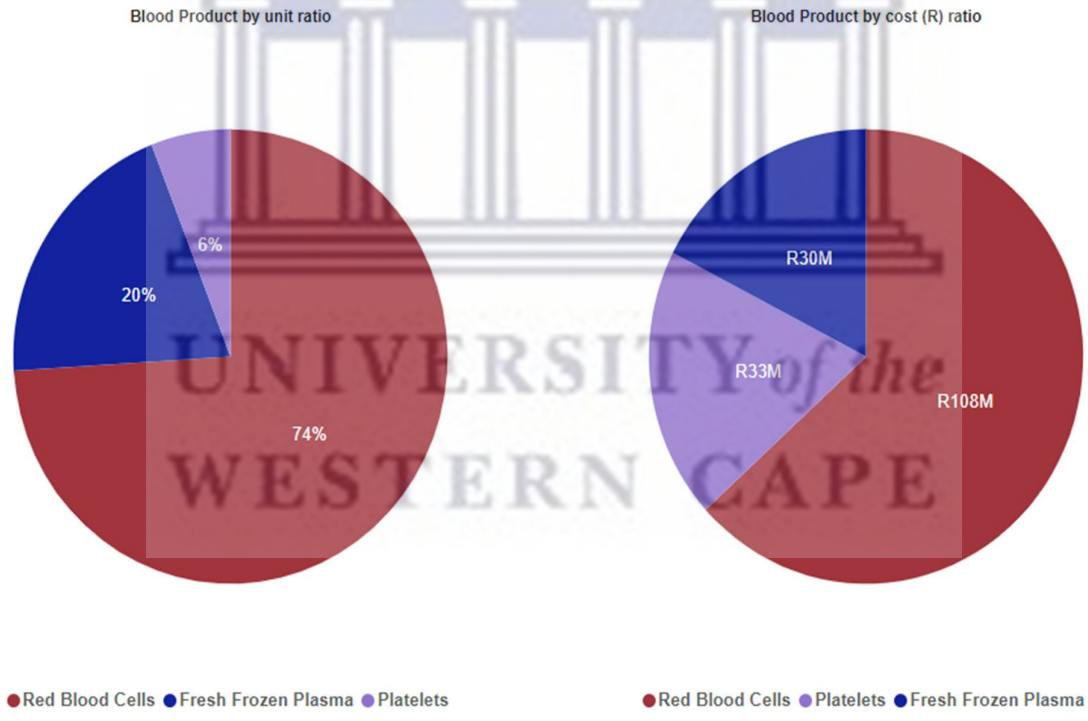

Figure 5: Product breakdown by unit and cost ratio (top 3 wards in the selected hospital)

Although the study focused only on the most commonly ordered product (RBC products), other billable terms were also identified in the data analysed, namely: human leukocyte antigens (HLA), stem cells, antibodies, albusol, DNA extraction fees, emergency fees, and BRB taxes. **Figure 5** shows the impact of these billable blood products on the overall cost of blood products.

4.3 Data fields collected

During the hospital visit, it was discovered that RBC orders and use information were recorded in a blood transfusion book (BTB). Each of the four hospitals visited kept the same book (with the same name). However, it was noticed that the data fields captured in the book varied from hospital to hospital and from ward to ward, as shown in **Table 4**. The table shows inconsistencies in the data collected from the four hospitals. Each hospital prioritises specific fields over others, depending on their particular needs. Edenvale Hospital collected the most data types (15 fields), followed by Kalafong Hospital with 13 fields, Charlotte Maxeke Hospital with 12 fields, and Kopanong Hospital with eight fields. Only the signature field is common to all the hospitals. This finding was significant due to the expectation that GDoH reports were standardised across all provincial hospitals.

Based on the WHO and SANBS clinical guidelines for using blood products in South Africa, a minimum set of data fields is prescribed as required for blood-related products and transfusions. The details of the prescript were discussed in the part of the literature review that refers to clinical guidelines on blood transfusions.

Table 4: Use of fields in each sampled hospital, compared with the list of fields captured in BTB and the Clinical Guidelines for the Use of Blood Products in South Africa (Gauteng Department of Health, 2018)

X = field captured, - = field not captured, O = field captured at selected hospitals

No	Field	Charlotte Maxeke Hospital	Kalafong Hospital	Edenvale Hospital	Kopanong Hospital	CL2 2018 Fields Captured	CL2 2018 Fields Not Captured	Remarks
1	Age of Patient	X	-	-	-	O		**Only captured at Charlotte Maxeke Hospital**
2	Contact - Clinician						-	**Not captured at the four visited hospitals**
3	Date - Sample collected						-	**Not captured at the four visited hospitals**
4	Date of Admission	X	-	-	-			**Not part of the CL2 fields**
5	Date of Birth						-	**Not captured at the four visited hospitals**
6	Date of Transfusion	X	X	X	X			**Not part of the CL2 fields**
7	Date units Received	-	X	X	-			**Not part of the CL2 fields**
8	Details - Person Drawing sample						-	**Not captured at the four visited hospitals**
9	Diagnosis	X	X	X	X	X		**Captured at the four visited hospitals**
10	Doctor's Signature	X	X	X	X			**Not part of the CL2 fields**
11	Gender						-	**Not captured at the four visited hospitals**
12	HB Level	X	-	X	-	O		**Only captured at Edenvale Hospital and Charlotte Maxeke Hospital.**
13	Hospital Number	X	X	X	X	X		**Captured at the four visited hospitals**
14	HPCSA or SANCA number						-	**Not captured at the four visited hospitals**

15	No of RBC Received	-	-	X	X			**Not part of the CL2 fields**
16	No of RBC Transfused	X	-	X	-			**Not part of the CL2 fields**
17	Nurse's Signature	X	X	X	-			**Not part of the CL2 fields**
18	Patient Blood Type	X	X	X	-			**Not part of the CL2 fields**
19	Patient Name	X	X	X	X	X		**Captured at the four visited hospitals**
20	Platelet Count						-	**Not captured at the four visited hospitals**
21	Prescribing Doctor's Name	-	-	X	X			**Not part of the CL2 fields**
22	Previous Transfusion						-	**Not captured at the four visited hospitals**
23	RBC Barcode	-	X	-	-			**Not part of the CL2 fields**
24	RBC Unit Number	-	X	X	-			**Not part of the CL2 fields**
25	Reason for discarded RBC	-	-	X	-			**Not part of the CL2 fields**
26	Remarks	-	X	-	-			**Not part of the CL2 fields**
27	Required Blood Product					X		**Captured at the four visited hospitals**
28	Special Notes					O		**Only captured at Edenvale Hospital.**
29	Surname	X	X	X	X	X		**Captured at the four visited hospitals**
30	Time - Sample collected						-	**Not captured at the four visited hospitals**
31	Time of Transfusion	-	X	-	-			**Not part of the CL2 fields**
32	Urgency						-	**Not captured at the four visited hospitals**

GDoH had developed SOPs to guide the collection of data for the processing of blood products for all hospitals. Due to the inconsistencies identified in the collected data, it was noted that data analysis could have limitations and may create a potential for misinterpretation of the data during reporting.

Table 4 lists data collection fields recommended in BTB and the Clinical Guidelines for the Use of Blood Products in South Africa (GDoH, 2018), compared with the data fields collected in the four hospitals included in this study. In **Table 4,** the highlighted grey fields are recommended that must be collected when ordering blood products (GDoH, 2018). Only field 12 is collected at Charlotte Maxeke Hospital and Edenvale. None of the four hospitals collect those data fields marked with the – sign. Blood traceability is a legal requirement stipulated in the WHO blood transfusion guidelines, known as 'vein-to-vein information' in the SANBS guidelines. An emphasis is made to collect as much information as possible for blood transactions. The information enables the right blood products to be administered to the right patient at the right time. The guidelines also require that records of life-threatening reactions during blood transfusions are kept and that information about the treating doctor and caregiver (nurse responsible for the patient care) is kept for accountability. However, the guidelines are oriented toward patient outcomes and clinical decisions, reiterating the same view in interacting with SANBS personnel. These findings suggest a misalignment between what hospitals record as 'data fields' for blood product transactions and the minimum data fields for blood products according to the SANBS and WHO guidelines. However, the concept might not be fully implemented due to the data gaps.

Traceability of blood products is a legal requirement in SA (National Health Act, 2003). Accurate information makes tracking and tracing blood products possible and provides accountability for units of RBC ordered by hospitals. Proper information delivery and standardised processes impact how doctors and nurses account for blood products used in their wards. The data fields collected in each visited hospital make it almost impossible to perform standardised data analysis in the four hospitals. In the next section, the data collected across the four hospitals show the challenges of inaccuracy and the discrepancies created when data fields are not standardised.

4.4 Barriers in the reverse logistics process of blood

4.4.1 Hospital background and breakdown

The previous section considered the background of hospitals. A product baseline was established, and RBCs were identified as the predominantly ordered products. The number of RBC units ordered between January 2020 and December 2021 was calculated and is shown in **Figure 6** below.

Hospital visits took place between February and March 2022. Edenvale and Kopanong Hospitals were visited in February 2022, and Charlotte Maxeke and Kalafong Hospitals were visited in March 2022. Visits were made during work hours to monitor health workers as they ordered RBC products. The main objective of the exercise was to map the RBC's forward and reverse logistics process through observation and information collected from operational reporting documents. The literature suggests that based on previous studies (Patil & Shetmahajan, 2014; Wamamba et al., 2017), cancer-related treatment, accident and trauma, and gynaecology treatment are known to consume the highest number of RBC products. The data analysis performed on the data presented in **Figure 6** supports this finding in the case of Gauteng. It was found that paediatric medical oncology, gynaecology, and resuscitation had the highest consumption of RBC products. Charlotte Maxeke Hospital, with a bed capacity of>1,200 beds, was found to have the highest number of RBC products, with 27,122 units, followed by Kalafong Hospital, with a bed capacity of >1,000 beds, with 14,135 units, Edenvale Hospital with a bed capacity of 400-800 beds, with a total of 9,366 units, and lastly Kopanong Hospital with a bed capacity of 200-800 beds, with 4,724 units.

When the data were narrowed down in each of the three hospitals, factoring the bed capacity, Kalafong was found to have the highest number of units ordered, with 7,540 units, followed by Charlotte Maxeke Hospital, with 5,374 units, Edenvale Hospital, with 5,221 units and finally Kopanong Hospital, with 2,468 units. These results were not expected. As Charlotte Maxeke Hospital is an academic hospital with over 1,200 beds, it was anticipated to have the highest patient headcount and visits per year compared to a non-academic hospital, such as Kalafong Hospital. The mismatch of numbers could be due to the closure of Charlotte Maxeke Hospital between April 2021 and November 2021 due to a fire incident that destroyed 50% of the hospital infrastructure (Sesona, 2021). Most of the patients were moved to another hospital, and, as a result, most of the wards of Charlotte Maxeke Hospital operated at low capacity, reducing the demand for RBC units during that period.

4.4.2 Hospital breakdown

Secondary data were generated between January 2020 and December 2021, covering the number of units of RBC ordered, consumed, and discarded. **Figure 6** shows a detailed view of the RBC units ordered and transfused within the four selected hospitals. Considering the top three wards with the highest RBC consumption in the four hospitals, Kalafong Hospital appears to have the highest number of RBC products ordered, followed by Charlotte Maxeke Hospital, Edenvale Hospital and Kopanong Hospital. As discussed in previous sections, these results were surprising, but the explanation was logically based on past events. The total combined number of RBC units ordered from the blood bank was found to be 20,603 units, with 10,508 units reordered as used. The figure translates to a usage rate of 51%. Resuscitation and casualty units at Kalafong Hospital were found to have the highest number of RBC units ordered, with 3,035.

In contrast, the casualty unit at Edenvale Hospital could not account for 100% of the RBC units ordered during the investigation period. Charlotte Maxeke Hospital represented almost 73% of ordered RBC units, followed by Edenvale Hospital at 65%, Kopanong Hospital at 43%, and Kalafong Hospital at 43%. Kalafong Hospital was also found to have the highest number of red blood units that could not be verified to have been used or not, at 71%.

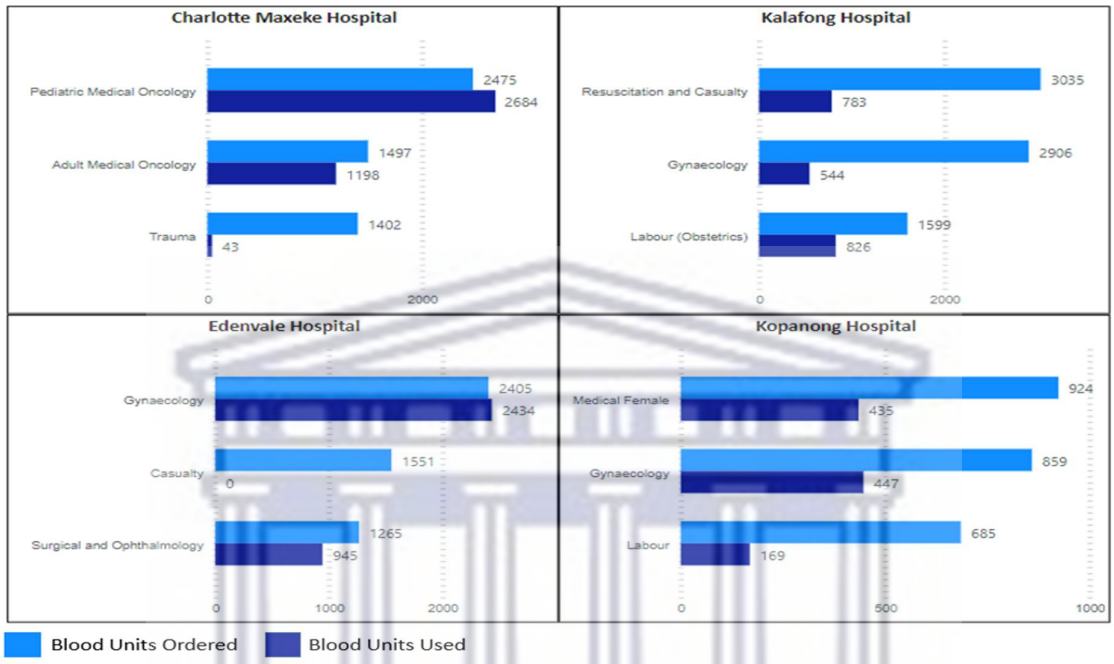

Figure 6: The top 3 wards visited for each of the selected hospitals

Figure 7 provides a high-level view of the number of RBC products ordered and used during the investigation and a graphical view of the results. The researcher analysed Operational data from GDoH and SANBS to derive the total number of RBC products ordered. The findings suggest that, on average, Kalafong Hospital contributed 37% of the total orders, which was the highest, followed by Charlotte Maxeke Hospital at 26%, Edenvale Hospital at 25%, and Kopanong Hospital at 12%. No trend was observed in ordering RBC units, as the monthly figures were found to vary. Still, it was observed that, during the investigated period, the highest number of RBC units ordered were in January 2020 (5%), November 2020 (5.3%) and March 2021 (4.7%).

The BTB records were analysed (see **Figure 7**) to derive the total number of RBC products used in each visited hospital over the period. As with ordering RBC units, no trend in using RBC units was observed, as monthly figures varied. The highest number of RBC units used during the investigated period were in January 2020 (5%), September 2020 (4.5%) and October 2021 (5.6%).

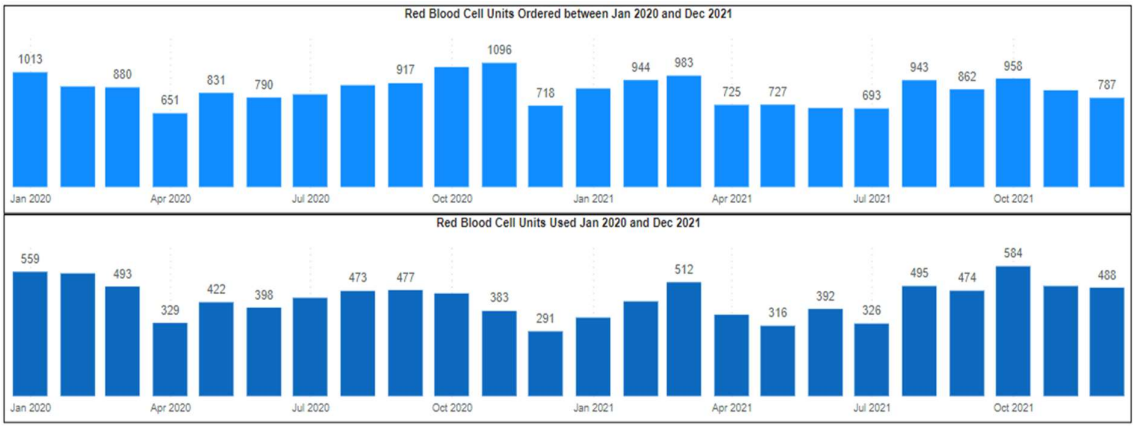

Figure 7: RBC units ordered and used between January 2020 and December 2021

A correlation coefficient was calculated to establish whether there is a relationship between the ordered RBC units and the RBC units used. The correlation coefficient between two variables (x, y) measures the strength of the relationship. The coefficient **r** is between -1 and +1, whereby a coefficient close to 0 means a very weak or no correlation, and a coefficient close to +1 means a stronger positive relationship. In contrast, a coefficient close to -1 means a strong negative relationship. The following equation was used to calculate the correlation coefficient between the two variables: RBC ordered (y) and RBC used (x).

$$\mathbf{r} = \frac{n(\Sigma xy) - (\Sigma x)(\Sigma y)}{\sqrt{\left[n\Sigma x^2 - (\Sigma x)^2\right]\left[n\Sigma y^2 - (\Sigma y)^2\right]}}$$

$$r = 0.6$$

The result suggests a positive relationship between the ordered RBC units and used RBC units. The results mean that for every ten units ordered, six were used, which leads to the conclusion that the number of ordered RBC units is directly proportional to the number of RBC units used. The outcome of the above result was observed across the four hospitals, and any future studies can replicate the results across the rest of the hospitals in the GDoH. The demand and supply of RBC units in the hospitals visited were found to be a clinical discussion. At the same time, the research will only focus on logistics and administrative-related challenges and, therefore, the impact of technology.

The BTB for each ward was used to extract information from blood transfusion records. This information included the number of units of RBC received and used (transfused). SANBS operation reports were used to validate the number of RBC units received versus RBC units ordered. The BTB records were confirmed to verify the total number of RBC units ordered and received with the number of units used. The following formula describes the relationship between the number of RBC units ordered and the number of RBC units used.

$$Rx - Ry = Rz$$

Rx = total number of RBC units ordered in the ward, data extracted from the operational report generated by SANBS.

Ry = total number of RBC units used in the ward, data extracted from the BTB completed by nurses.

Rz = difference between Rx and Ry, units found in the SANBS report on blood ordered and delivered to a specific ward, less recorded as used in the BTB.

A positive value of Rz means that some RBC units were not recorded in the BTB, and no other record could be found to show if the units were used.

A negative value of Rz means that the number of RBC units used is greater than the number of RBC units ordered. The negative value was observed when patients were transferred between wards (for example, from the casualty ward to the gynaecology ward or from accident and emergency to the ICU), with RBC units already ordered/delivered. The ward that receives the patient will register the RBC unit in the BTB as transfused. However, the actual unit/s ordered will be reported by the transferring ward.

Possible reasons for understanding what could have happened to these units were explored. However, no documented information was available during the data collection process. Suggesting that the units might have been discarded and never recorded in the BTB. During data collection, SANBS indicated that a report named 'blood waste report' was generated monthly by SANBS and sent to hospitals. Administrative personnel from the South African National Blood Service (SANBS), situated at the blood bank, were duly approached to ascertain the existence of any pertinent records about the units mentioned above. Subsequently, it was established that a blood waste report had been furnished, delineating the quantity of Red Blood Cell (RBC) units requisitioned and the number of RBC units returned to the blood bank. The report provided a high-level view of the blood returned to the blood bank of each hospital. The provided data could not be linked at the ward level, making it impossible to assign each figure to the participating wards in the study. The figure provided in the blood waste report was considered complete. This figure was assigned the symbol **Rw**.

The formula to calculate the accumulated waste was amended where Rz + Rw = n:

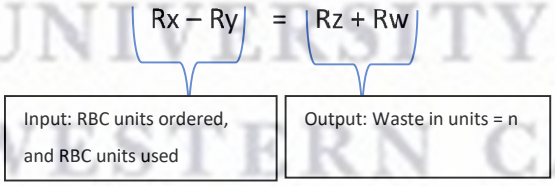

Table 5 summarises the results for each of the four selected hospitals. Based on the information received from the SANBS blood waste report, it was found that Kopanong Hospital does not send unused RBC units back to the blood bank. Therefore, the waste report did not report data or provide any reason for unused RBC. This finding was a concern that could not be explained by the provincial office responsible for blood management. However, the provincial office has indicated that ongoing discussions with the hospital will resolve the challenge. Worryingly, the hospital stated that it was unaware that sending unused blood products back to SANBS was a legislative requirement.

Table 5: Summary report of estimated RBC waste

Hospital Name	Rx	Ry	% Found	% Not Found	Rz	Rw	Est Wastage = n
Charlotte Maxeke Hospital	5374	3925	73%	27%	1449	1511	2960
Kalafong Hospital	7540	2153	29%	71%	5387	291	5678
Edenvale Hospital	5221	3379	65%	35%	1842	318	2160
Kopanong Hospital	2468	1051	43%	57%	1417	0	1417
Totals	**20603**	**10508**	**51%**	**49%**	**10095**	**2120**	**12215**

An estimated average of 57% of red blood cells was found to have been wasted in the four hospitals. This slightly higher figure supports the initial estimate of 40% wasted RBC units, according to the SANBS data. The baseline was established for ordered, used and estimated waste, and the relationship was established. The focus was moved to individual hospitals.

4.4.3 Individual hospital discussion

Charlotte Maxeke Hospital is the largest hospital investigated in this study. The three wards with the highest number of ordered RBC units ordered a combined total of 5,374 RBC units, with an estimated Rand value of R13 million from January 2020 to December 2021. On average, the hospital orders two RBC units per patient, and 27% of the RBC units ordered were not recorded in the BTB. The paediatric medical oncology unit recorded all ordered RBC units, but the number of RBC units recorded in the BTB was higher than the number of RBC units ordered. This phenomenon was attributed to patients being transferred to the ward with already-ordered RBC units or while the patient waited for a bed to become available. However, it was also observed that the hospital's trauma unit did not keep records of the RBC units, with only 43 RBCs being recorded in the BTB as used of the 1,402 RBC units ordered. This gap in record-keeping is happening despite the Trauma Unit being the main organiser of the hospital's blood management committee. The formula above suggests the hospital has an estimated waste of n = 2,960 units (55% of total units). These RBC units might be considered waste since no records support their used or transfused.

Kalafong Hospital is the second largest among the hospitals selected for the study. The three wards with the highest number of ordered RBC units had a combined total of 7,540 RBC units, with an estimated Rand value of R14 million, from January 2020 to December 2021. On average, the hospital orders two RBC units per patient. However, it was found that, on average, the resuscitation and casualty ward ordered three units of RBC per patient. The data indicate that 71% of the ordered RBC units were not recorded in the BTB. The gynaecology ward could provide records for only 19% of the ordered and used units, and the resuscitation and casualty department could provide records for only 26% of the ordered and used RBC units. Using the formula derived, the result suggests that n = 5,678. 75% of RBC units could be considered waste due to the lack of records available to support their use or transfusion. The hospital was found to need better record-keeping and more accountability for the blood products used. Although the hospital was the second largest among the selected, its consumption rate was higher than the larger hospital (Charlotte Maxeke), and the reasons for this need

further investigation. An identified concern was the nursing staff's lack of knowledge about the hospital's blood management committee.

Edenvale Hospital is the third largest of the hospitals studied. The three wards with the highest number of ordered RBC units had 5,221 RBC units, with an estimated Rand value of R10 million, from January 2020 to December 2021. On average, the hospital orders two RBC units per patient. It was found that the gynaecology, surgical and ophthalmology wards kept a good record of the number of units of RBC units ordered and used. The casualty ward, however, did not keep records of the units used and transfused. Using the formula derived above, the result suggests that n = 2,160 (41%). The 2,160 units of RBC could be considered waste due to the need for more records to support their use or transfusion. Nurses in charge of the visited wards indicated that they did not know about the existence of the hospital's blood management committee. The revelation was a concern, as the GDoH SOP refers to this committee as an oversight body to monitor and manage blood use at the hospital level.

Kopanong Hospital is the smallest hospital among those selected for the study. The three wards that ordered the highest volume of units were responsible for ordering 2,468 RBC units, at an estimated cost of R4 million, between January 2020 and December 2021. While, on average, the hospital orders two RBC units per patient, the gynaecology and female medical wards could provide records for only 50% of the RBC units ordered and used, and the labour ward could provide records for only 24% of the RBC units ordered and used. Hospital record-keeping was found to be very poor. The hospital showed little responsibility for managing and monitoring the use of blood products in general, and there needed to be data on unused RBC units sent to the blood bank for incineration. The hospital has a dedicated person to monitor and manage this use, but accountability was challenging. It was determined that 1,417 RBC units (57%) could be considered waste due to the lack of records available to support their used or transfusion. During a conversation with healthcare workers, doctors were found to be the only people authorized to order blood products for patients. Patients rotate between doctors, which results in multiple orders being placed for the same patient. This practice is considered a cause of some of the waste identified in the hospital. According to specific accounts, sessional doctors (doctors not working full-time at a hospital) were also identified as people who tended to order multiple blood units simultaneously. As with other hospitals above, another identified concern was the lack of nursing knowledge about the existence of a hospital blood management committee.

Although there have been several studies on blood transfusions across developed and developing countries, the focus has been on clinical outcomes. This focus was indicated on the key indicators tracked by the SANBS. Over time, WHO and SANBS have provided guidelines on blood use in clinical interventions for SA and countries worldwide to support the use of blood products. This research study has established that the GDoH has developed SOPs based on the above guidelines. However, by observation, poor adoption and communication are suggested as the root cause of the lack of SOP implementation and monitoring. The study has shown the volume of RBC units consumed in the selected hospitals and the significantly high number of units that could not be found in the records as used or discarded. These unaccounted units were estimated to be blood waste not reported by hospitals. This suggestion was supported by the nurses responsible for capturing information in the BTB. The finding also suggests that the blood management committees within hospitals are not efficient and

effective. The quality of information, recording, and data storage during blood transfusions is critical. It is becoming clear that access to information is key to successfully monitoring blood units.

This study provides a clearer perspective on the logistics process for ordering, transporting, and returning blood products. It also helps to understand the challenges related to the RL of blood products and the factors that affect this process. The data analysed and discussed in the previous sections show the extent of blood waste generated by the selected hospitals. Mapping the process provides a better view of the components within the process, their contribution to blood waste, and the root cause factors. With the amount of blood product waste estimated and the information derived from the data analysis, a variable 'estimated waste = n' has been defined and can be used to measure technology's impact on the RL of blood products. Reducing the variable when technology and logistics methods are applied will support the hypothesis of this research study.

4.5 Mapping the reverse logistics process of blood from PHFs to on-site and remote blood banks

4.5.1 Process mapping

The previous section covered the breakdown of the categories of products, RBC units per hospital, and a formula to identify waste in the four selected hospitals, using primary and secondary data collected from visits to the identified wards. This section maps the forward and reverse logistics of RBC products.

Based on the information collected from each hospital visited, the four hospitals do not have a standard procedure for ordering RBC products, recording their use, and the return process.

4.5.2 Blood process for hospitals using remote blood banks

Of the four selected hospitals, Edenvale Hospital and Kopanong Hospital did not have an on-site blood bank. Edenvale Hospital orders blood from the Charlotte Maxeke Hospital blood bank, which is 14 km away, and Kopanong Hospital orders blood from the River Square Shopping Centre, which is 7 km from the hospital. Edenvale and Kopanong Hospitals use internal personnel to order and transport blood products.

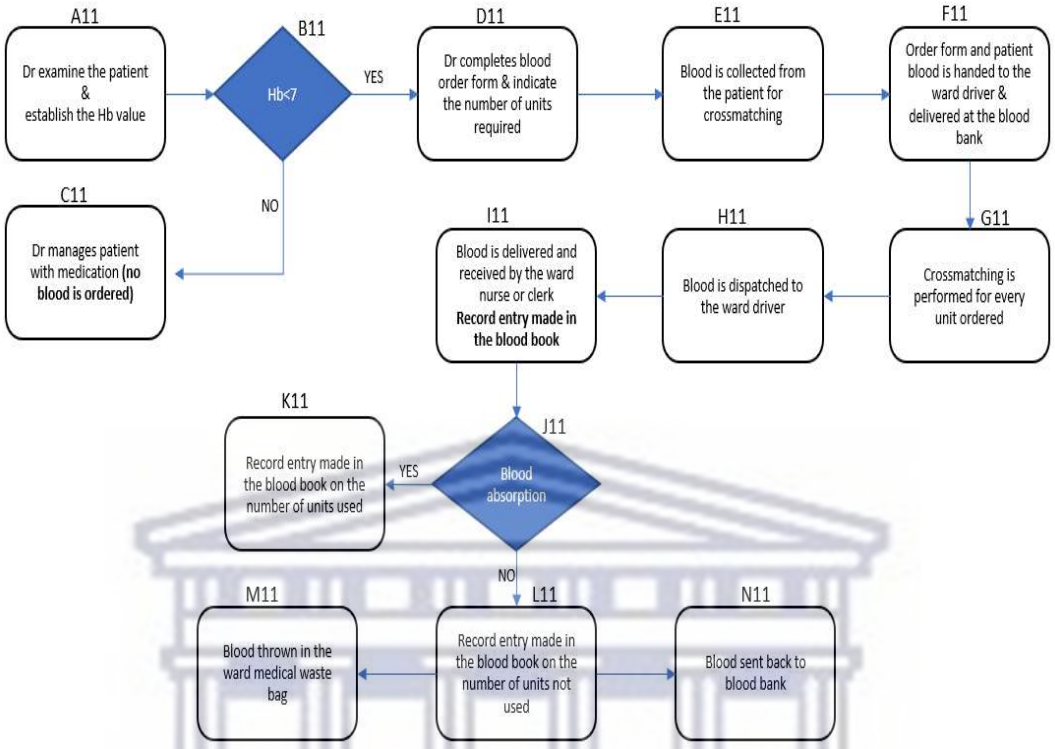

Figure 8: Mapped Process flow to order blood at Edenvale and Kopanong Hospitals (off-site blood banks)

Figure 8 shows a mapped process flow diagram to order RBC units in a hospital with an off-site blood bank. The diagram uses labels A11 to N11 to refer to each stage of the process flow, and each label is explained below.

A11: The treating doctor examines the patient to establish the level of haemoglobin (Hb) to decide whether blood is required using guidelines from the SANBS and WHO on clinical blood transfusion practice (CTP).

B11: Patients with Hb <7g/dl will likely need to receive a blood transfusion (clinical transfusion practice, n.d.). If, however, Hb >7g/dl, the treating doctor will manage the clinical signs and symptoms of the patient using medication to prevent significant morbidity or mortality (C11).

D11 and E11: The patient's demographic data (as indicated in **Table 4**) and clinical information are used by the treating doctor to complete the blood order form. At this stage, a blood sample is collected from the patient using a compact kit to perform cross-matching in the blood bank. The process ensures that the correct blood is sent to the right patient (WHO, 2002).

F11: The ward driver drops off the blood order form and blood sample at the blood bank, and once the requested blood is ready for collection, the driver collects and delivers it to the ward.

G11: Cross-matching is done and completed. The cost is R900 for every cross-matching RBC unit charged to the GDoH.

H11: Because the blood bank is located outside the hospital, the ward driver signs for the product before it leaves the blood bank, as well as on arrival at the ward, to confirm delivery. As a result of the blood bank being located outside the hospital, doctors reported uncertainty about the availability of blood as and when it is needed. The concern is also supported by a study in Bangladesh by the WHO (WHO, 2002), which found that

doctors in hospitals using external blood banks could not meet the one-unit time target for all RBC orders. The hospitals have the option to use the BRB box system discussed in the literature review. The system preserves the useful unit and extends the product's life by creating a constant temperature and humidity for a 12-hour cycle. However, due to the cost associated with the BRB system, doctors are discouraged by the clinical managers from using the system.

I11, K11: After receiving blood, Edenvale Hospital recorded the number of units received in the BTB for each patient and the number of units transfused.

L11: Edenvale Hospital recorded in the BTB the details of the RBC units that were not transfused (discarded), the reasons the units were discarded and whether the discarded unit was returned to the blood bank or not. Meanwhile, Kopanong Hospital did not record in its BTB the number of units of RBC received for each patient, and only the units of RBC that were transfused were recorded in the BTB. The hospital did not record information on the discarded RBC units or whether they were returned to the blood bank. Blood traceability is a standard practice recommended by SANBS and WHO in clinical blood transfusion practice. The information gaps in the units of RBC received, used, and discarded mean that the information required by top management for data-driven decisions is impossible.

4.5.3 Blood process for hospitals with on-site blood banks

Of the four selected hospitals, Charlotte Maxeke Hospital and Kalafong Hospital each have an on-site blood bank that operates 24 hours a day. **Figure 9** shows a mapped process flow diagram to order RBC units for both hospitals. The diagram uses labels A12 to M12 to reference each stage of the process flow, and each of these stages is discussed in detail below.

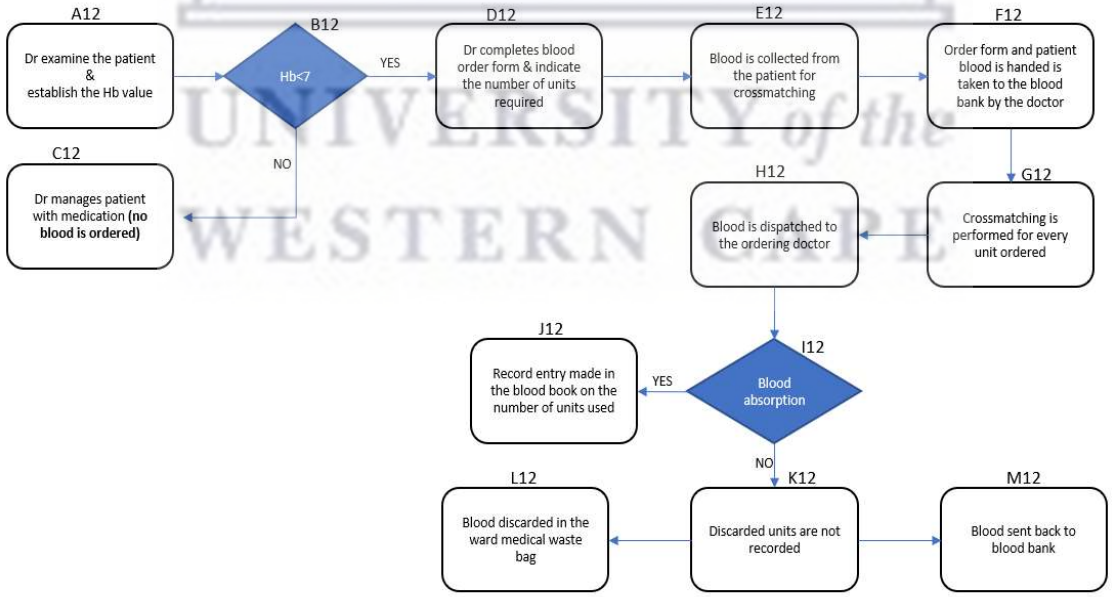

Figure 9: Mapped Process flow of blood ordering at Charlotte Maxeke and Kalafong Hospitals (on-site blood banks)

The action that triggers the need for a blood transfusion is similar for hospitals using on-site and off-site blood banks (A12-E12). However, the hospitals with an on-site blood bank do not require a driver to collect blood and

deliver the blood sample and the order form for the blood bank. Doctors in such hospitals will take the blood sample and the order form to the blood bank (F12).

G12: for every unit of RBC ordered, a crossmatch exercise is performed (SANBS, n.d.; WHO, 2002) to match the patient's blood to the correct blood type. The action is a repetitive process the costs R900 for every crossmatch that is performed. The process can potentially increase the cost of ordering blood if the ordered blood is not used or discarded.

H12: Ordering doctors are notified once the order is ready for collection. The order is sent to the doctor and taken to the ward. At Charlotte Maxeke Hospital, the nurse in the ward records the RBC units in the BTB. At Kalafong Hospital, there was little or no accountability for recording RBC units. The BTB at Kalafong Hospital was found to have little information on the RBC units ordered from the blood bank. Upon observation, communication between doctors and nurses was unclear, resulting in poor data quality recorded in the BTB.

I12: Blood is transfused, and this should then be recorded (J12). At Charlotte Maxeke Hospital, data was found to be collected on the number of units transfused, unlike at Kalafong Hospital, where this was not done.

K12: If unused RBC units are discarded, information is expected to be available on why the RBC unit was not used. Unused units must be returned to the blood bank for incineration (M12). However, Kalafong Hospital returned a deficient number of unused units based on the discussion on L12. The low number of RBCs was also reflected in the SANBS blood waste report. Neither hospital had a documented standardised procedure to return unused blood to the blood bank.

4.5.4 Summary

The mapped process can only describe the forward logistics of the RBC units. Whether the hospitals had an off-site or on-site blood bank was the same. The reverse process of returning unused blood to the blood bank was a gap already identified at this point.

The communication breakdown between nurses and doctors contributed to the poor recording of information on RBC units ordered and used. The data discussed in the previous section also showed that the resuscitation and casualty ward ordered, on average, three RBC units per patient, resulting in a high number of unrecorded RBC units. SANBS assumes that hospitals using an off-site blood bank order a higher number of RBC units per single patient than those with on-site blood banks due to closing the need for additional units in case of emergency. However, Kalafong Hospital was found to have, on average, two units of red blood cells ordered per patient request. In contrast, hospitals with on-site blood banks were found to order fewer units of RBC per patient compared to hospitals with remote blood banks.

As indicated earlier, clinical blood transfusion practice recommends recording a set of data fields during blood transfusions (SANBS, 2014). The data suggest that only a few of these data fields are collected in the four hospitals visited. In addition, a discrepancy was observed between fields collected in each of the four hospitals and those recommended by the WHO and SANBS. The RL process depicted in **Figure 2** (see page 9) suggests that a process must be documented and implemented to allow the return of products from the original manufacturer's distribution. However, this was contrary to what was observed in the four selected hospitals. Based on observation and interactions with nursing staff, it is clear that there is currently no standardised process to facilitate the return of unused blood to the blood bank. Therefore, the first recommendation of this

study is a proposal for a standardised forward logistics process for blood products and the development of a RL SOP. This recommendation can be achieved by adopting logistics methods such as just-in-time, widely used in the market for perishable goods, and on-demand orders used by online food services to deliver food when an order is placed, which is also used in the motor industry.

The clinical guidelines for the use of blood products in South Africa discussed in the literature review recommend a five-stage process for blood logistics, with the central focus of the process being the safety of blood transfusions and clinical patient outcomes in hospitals. The approach was also highlighted during a discussion with a SANBS doctor, the lead consultant on blood management for Gauteng province. A conversation with the Deputy Director of GDoH Clinical Support Service revealed that their primary focus in monitoring blood use is to reduce costs and promote accountability. Thus, it is evident that there is a misalignment between the outcome expected by SANBS and that highlighted by GDoH. Therefore, the second recommendation that arises from this study is the need to realign the expectations of the supplier (SANBS) and the consumer (GDoH).

The logistics process mapping, as shown in **Figure 8** and **Figure 9** above, was carried out with the help of nursing personnel working in the hospitals visited. However, they are not involved in the ordering process, resulting in limited information being captured in the BTB. Only doctors can order blood products for patients in the hospitals visited. However, during a discussion with some nurses, it was indicated that, in private healthcare, nurses can order blood products, provided that the treating doctor approves. As a result, private hospitals record more information on blood transfusion transactions (SANBS, 2021).

SANBS estimates that 40% of RBC units ordered in GDoH hospitals are waste. The data analysed for this study suggest that the percentage of waste might be even higher. A significant concern identified is that each hospital cannot provide documentation on returning unused blood to the blood bank. The underlying reasons for the return of unused blood units to the blood bank were also inconsistent. Some of the reasons expressed by informants were 'we do not know how to return blood', 'SANBS requested hospitals not to return unused blood since the start of the Covid-19 pandemic', and 'doctors were just not interested in informing nurses if ordered blood would still be used after long storage in the ward refrigerator'. These statements highlight the underlying problem of accountability within visited hospitals.

4.6 Waste in blood products

4.6.1 Blood handling and transportation

Based on the SANBS policy (SANBS, 2014) discussed in the literature review, blood units should be returned to the blood bank, provided that the cold chain is maintained and blood units are returned within 10 hours of dispatch. The 10-hour return policy depends on the blood units transported in a BRB box. Using the BRB box results in a levy being payable to SANBS, which has been shown to discourage doctors from using the BRB box. GDoH is charged R1,200 for a 24-hour BRB box and R237.62 for a 12-hour BRB box. **Figure 10** shows a process for handling and storing RBC units. A temperature between 20^{o}C and 24^{o}C must be maintained from collection to transfusion to keep the product in the desired usability condition. The preparation starts at the collection point at SANBS blood bank, and the temperature must be maintained between +2 ^{o}C and +6 ^{o}C.

As observed during visits to the four hospitals, the RBC units are delivered packaged in brown paper bags (refer to stage I11 in Figure 8 and stage H12 in Figure 9 and see **Figure 11** below), making it almost impossible to

monitor the cold chain. Brown bags were reported to be the most effective for emergency requests based on SANBS and did not incur additional costs. The effect of distributing blood in brown bags and the inability to monitor and maintain the required parameters of the SANBS policy means that once the RBC unit leaves the blood bank, it cannot be returned for reimbursement and reuse.

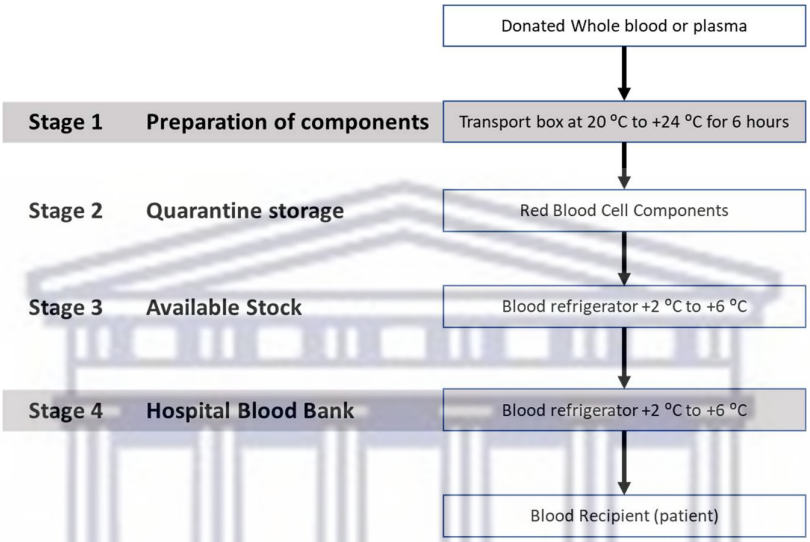

Figure 10: Blood cold chain process: collection to transfusion (WHO, 2002)

Brown bags are prone to breakage, and identification labels can tear off the package, posing a risk that the patient may receive incorrect blood. The four hospitals visited appear to have used brown bags to deliver RBC units. The need for doctors to obtain written approval to use BRB boxes was identified as a risk, as it can delay the delivery of blood in emergency cases, with the potential for patient death as a result. Due to the costs associated with BRB boxes and the required approval, causing complexity for daily use, the adoption of the boxes was found to be very low. Several logistics methods, such as just-in-time, milk run, and lean, might address some of these challenges. However, a change and adoption process that focuses on and includes consultation with the main stakeholders, such as doctors, nurses, clerks, and others, will need to be considered, regardless of which logistic method is adopted.

Figure 11: Image of blood units delivered to the ward

It was found that the understanding and expectation of the processing and handling of blood products differs between doctors and nurses. Doctors appear to be interested in the clinical outcome of blood transfusion. At the same time, nurses (responsible for keeping records) are primarily interested in the number of units used and what is wasted. Meanwhile, GDoH's interest lies in reducing the cost of blood products without impacting the delivery of services. Nothing has been done to evaluate the cost implications of using BRB boxes, meaning that the system might not change soon, and the current process prohibits blood return for redistribution. The non-refundable fee for cross-matching blood on every RBC unit dispatched, irrespective of whether the unit is used, is a significant cost driver of blood products and ultimately a fruitless and wasteful expenditure for GDoH.

4.6.2 Blood waste breakdown and factors

SANBS defines blood wastage as unused blood units returned to the blood bank for incineration. This definition has been accepted and used to compile a monthly blood waste report. Using the results derived from the analysis of primary and secondary data (data collected during the observation and information from the BTB book), it was found that not all hospitals returned unused blood to the blood bank. Only 50% (two) of the hospitals studied recorded information on discarded RBC units in the BTB, including reasons why the units were discarded or not used.

The introductory section of the investigation provided a classification of blood wastage into four categories: A-D, as described in **Figure 1.** This study focuses on category D: blood units sent to hospitals but unused (transfused) (see stage L11 in **Figure 8** and stage K12 in **Figure 9** in the mapped process). It was found that once

a decision was made not to transfuse, the blood units were returned to the blood bank by Edenvale and Charlotte Maxeke Hospitals or discarded as medical waste by Kalafong and Kopanong Hospitals.

Any unit of blood ordered will be dispatched once cross-matching has been completed. **Figure 12**, below, shows the eight reasons why blood is discarded or not used (see stage L11 in **Figure 8** and stage K12 in **Figure 9**). The evidence points to 36% of blood units discarded in the wards not being recorded in the BTB. Meanwhile, 24% of the blood was found to have been discarded due to patients being discharged before a blood transfusion, and 20% due to the patient's demise before or during a blood transfusion. The remaining percentage of blood discarded was due to patients reacting to blood transfusion, changes in the haemoglobin (Hb) level before transfusion, patients not being found, and patients being transferred to another ward or hospital. The WHO recommends that blood be discarded if the cold chain has been broken for at least 30 minutes, the original seal is broken, or the blood unit undergoes haemolysis, clotting, or contamination. These conditions are linked to poor monitoring of the cold chain of blood products during transit and storage in hospitals.

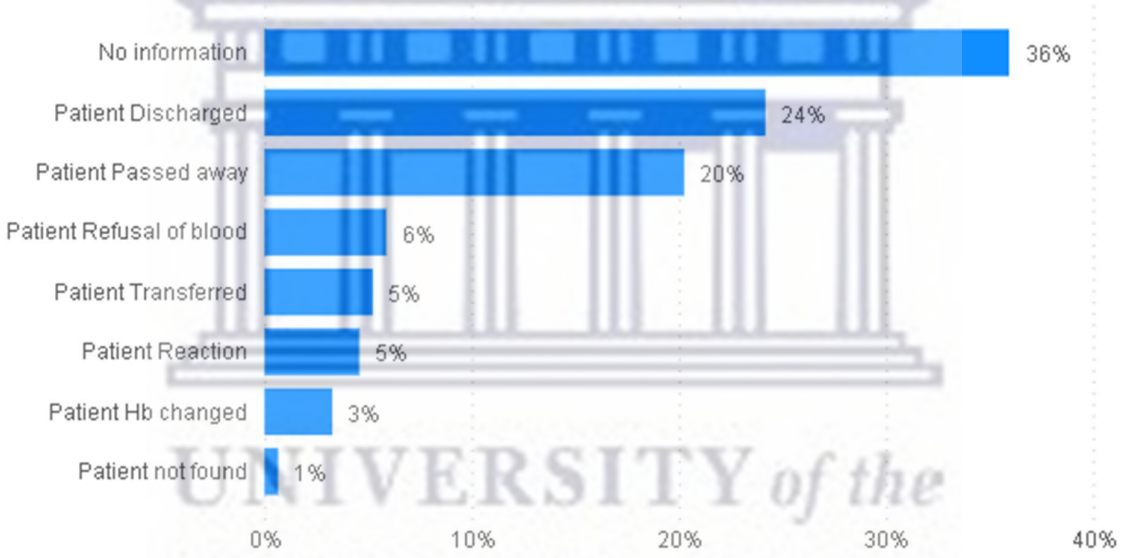

Figure 12: Reason for discarding blood-based on BTB

The general underlying reasons for the return of unused blood units to the blood bank were also unclear. Some reasons include the following: 'we do not know how to return blood', 'SANBS requested that hospitals do not return unused blood since the start of the Covid-19 pandemic', and 'doctors were just not interested in informing nurses if ordered blood would still be used after long storage in the ward refrigerator'. **Table 6** summarizes why blood is discarded, with process stages and factors, and suggests mitigations.

Table 6: Reasons for discarding blood-based on BTB and process stages

#	Reason	Total %	Stages in the Process indicated in Figures 8 and 9	Factors	Recommended Mitigation
1	No information	36%	M11, K12	Communication	Communication between doctors and nursing staff must be improved through PBM committees. Technology can be used to automate the process and digitise documentation for future reference.
2	Patient discharged	24%	D11, E11, D12, E12	Administrative Process	An SOP to monitor and control the follow-up process during admission and discharge of patients must be developed, incorporating logistics principles such as just-in-time.
3	Patient passed away	20%	D11, D12	Clinical Process	SANBS and WHO clinical practice guidelines must be implemented to manage the blood order process for most known clinical conditions and when treatment becomes palliative care.
4	Refusal of blood	6%	A11, A12	Administrative Process	An SOP must be developed to monitor and control the process to be followed during admission and discharge of patients, and technology must be used to track patient demographics to provide the religious status of the patient.
5	Patient transferred	5%	J11, J12	Administrative Process	An SOP must be developed to monitor and control the process to be followed during the admission and discharge of patients.
6	Patient reaction	5%	J11, J12	Clinical Process	Collecting and digitising patient risk factors during admission and discharge will illuminate the risk of receiving incorrect blood and reduce adverse events related to blood transfusion.
7	Hb changed	3%	B11, B12	Clinical Process	SANBS and WHO clinical practice guidelines must be implemented to manage the blood order process using haemoglobin (Hb) as a clinical deciding factor.
8	Patient not found	1%	A11, A12	Communication / Administrative Process	An SOP must be developed to monitor and control the process to follow during the admission and discharge of patients, and technology can be used to track patients while admitted to the hospital. This will reduce the risk of patients disappearing from the hospital without a trace.

As indicated earlier, the reasons identified for discarding RBC units are based on the information recorded in the BTB. As discussed in previous sections, this information is collected and recorded by the nursing staff in the wards. The suggested mitigations can be improved by using technology to capture, automate, and digitise the collection of information related to the pre-transfusion and post-transfusion of RBCs. It is proposed that this will improve communication between doctors and nursing staff by providing access to information when necessary, regardless of location. It will also improve the administrative process factors identified in **Table 6.** Administrative and clinical factors will require collaboration between sessional doctors, resident doctors, nurses, and the blood management committee at each hospital. The impact of technology, as discussed in the literature review, requires optimal processes with logistics methods in place.

4.7 Responses to the electronic survey questionnaire

This study used a stratified random sampling procedure to identify key players in the ordering and processing blood products. Participants in the identified observation protocol were invited to participate in the electronic survey questionnaire (ESQ), with 28 responses being received or a response rate of 38%.

The ESQ included a branch that filtered participants into two groups (A and B), as shown in **Figure 13.** The filter ensured that question 4 was answered only by participants with relevant clinical knowledge and experience (medical doctors). The flow of the ESQ was designed to be easy to follow, as indicated below.

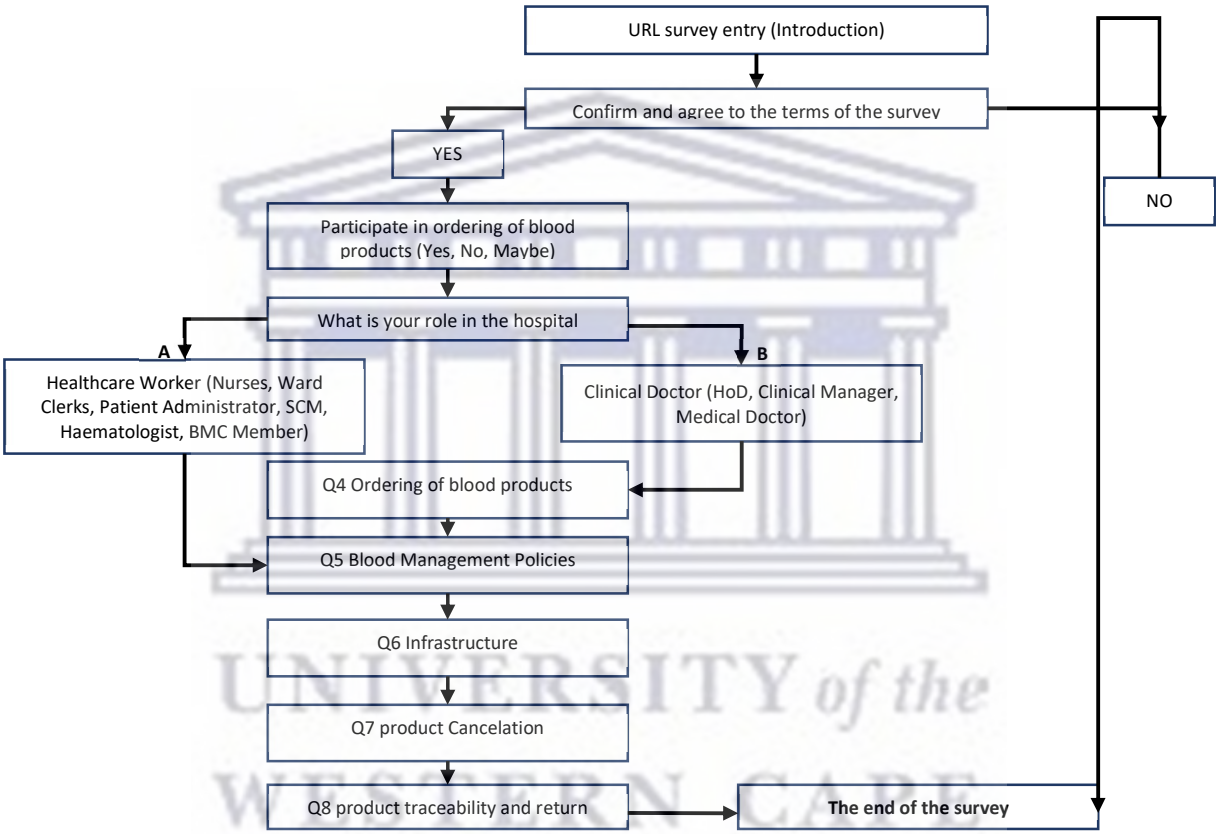

Figure 13: Electronic survey questionnaire flow

Most of the survey respondents reported being involved in the overall process of ordering blood products in their respective units or wards. Responses suggested inadequate communication between nurses and doctors about the ordering and using blood products in hospitals. Respondent doctors seemed to agree that more than 60% of patients require a minimum of one RBC unit for the first transfusion and suggested having alternative protocols such as Massive Transfusion Protocol (MTP) and Maximum Surgical Blood Ordering Schedule (MSBOS) to reduce the waste of blood products. There were mixed responses about whether the hospitals had policies to guide the decision-making process when ordering blood products and policy monitoring. Such policies are crucial for monitoring and using blood products. It has been shown that the absence of such policies results in poor adherence to processes aimed at preserving blood products (SANBS, 2014; WHO, 2002). ESQ analysis also

suggested that travel time and logistics for blood products determine the average number of RBC units ordered for the first transfusion. The ESQ analysis also supported the reasons for unused RBC products being: the patient not being found after delivery of the RBC units (12%), the patient passing away before transfusion (8%), changes in Hb level before transfusion (8%), and the patient being transferred to another ward or hospital before transfusion (8%). Lastly, the ESQ results suggested that respondents believe that the visited wards return unused RBC units to the blood bank and that respondents understand the importance of returning all unused blood products. Findings from BTB and SANBS report analysis did not support this latter point.

4.7.1 ESQ Participants' roles and responsibilities

ESQ participants were asked to indicate their role in the ward or hospital, which allowed for separating responses based on roles and responsibilities. **Figure 14** shows that 61% of the participants were involved in ordering blood products in their respective wards or hospitals. **Figure 14** also shows that 36% of the respondents were not directly involved in the ordering process, and 4% were uncertain of their role. Furthermore, the two categories of participants clarified were secondary players responsible for receiving units of red blood cells (administrative staff) or participants in the transfusion process (nurses).

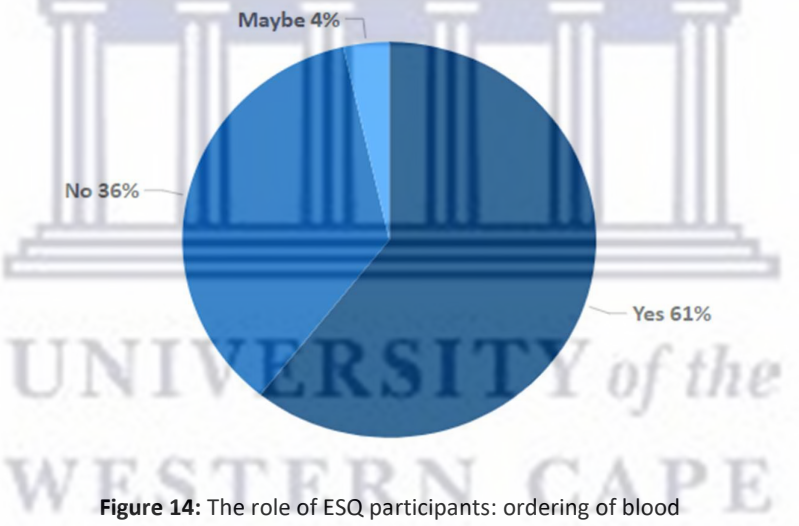

Figure 14: The role of ESQ participants: ordering of blood

According to the results shown in **Figure 15,** the majority of ESQ participants were nurses (43% of ESQ respondents), 18% were members of the blood management committee and coordinators, 14% were department heads, 14% were medical doctors, 7% were medical technologists, and 4% were information and communication technologists.

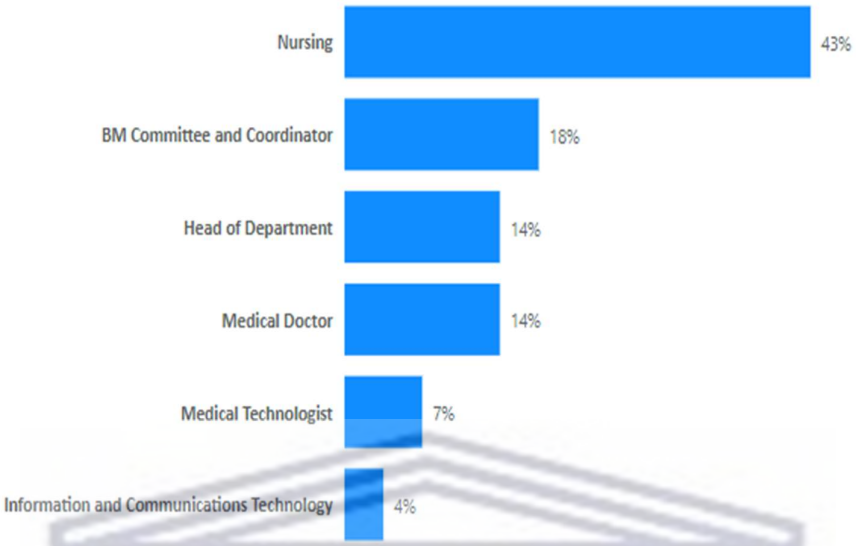

Figure 15: ESQ participant occupation

The questionnaire also included the 'other' option to capture roles not identified during the sampling design.

4.7.2 Ordering of blood products

According to the results shown in **Figure 16**, 25% of the participants strongly agreed that MTP and MSBOS are essential to guide junior doctors on ordering requirements. However, during observation visits to the selected hospitals, most nurses seemed to suggest that the lack of guidance from the senior doctors resulted in the junior doctors ordering incorrect products, resulting in the waste of RBC units. The ESQ findings also indicate that 25% of the participants strongly agreed that their hospital or ward promotes using a returnable basis system. The use of the returnable basis system contradicts the data collected from BTBs and SANBS reports. The results show that 13% of the participants, mainly doctors, agreed strongly that 60% of their patients require only one unit of RBC for the first transfusion. However, observation and BTB seem to suggest the opposite.

There is a 50% disagreement with the notion that 10% of patients require more than three units of RBC for the first transfusion. However, Kalafong Hospital was found to order, on average, three units of RBC for the first transfusion, contradicting the above assertion. As a result, the hospital was estimated to have the highest number of wasted RBC units among the four hospitals.

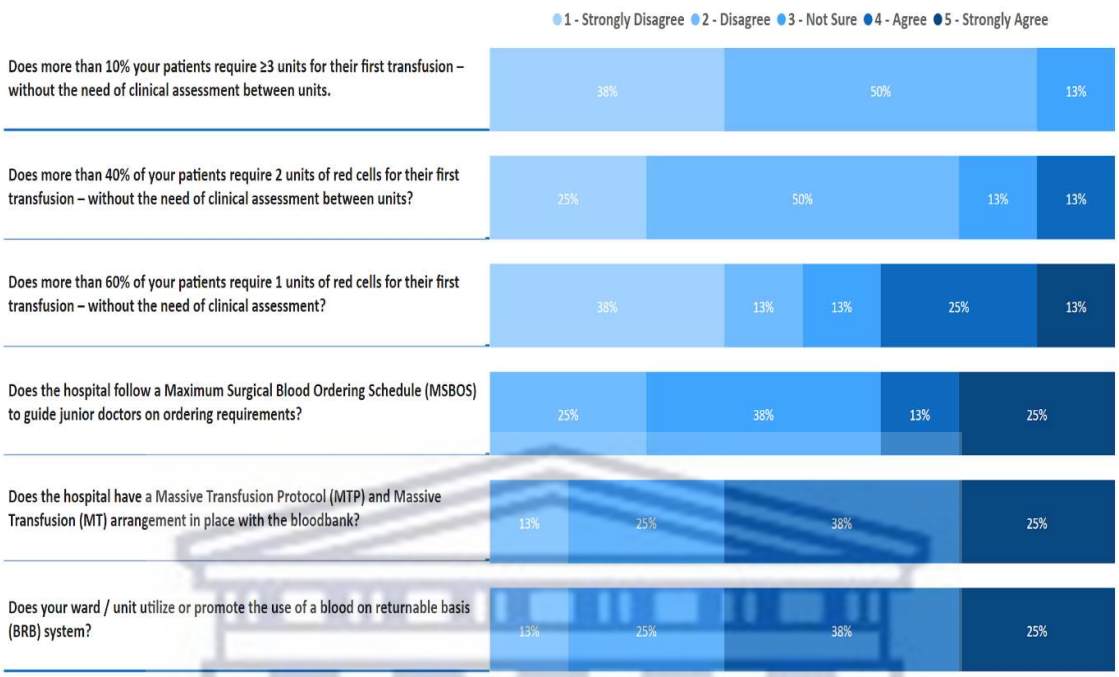

Figure 16: Ordering of blood products (Question 4)

4.7.3 The reason for unused RBC units

As previously shown, on average, 57% of RBC units end up as waste, which is somewhat higher than the figure of 40% estimated by the SANBS. According to the results shown in **Figure 17,** most of the survey respondents agreed that 'very frequent' cancellations of RBC unit orders are due to either the patient not being found, the patient passing away before delivery, the Hb level changing before transfusion, or the patient being transferred to another ward or hospital before transfusion. However, these results contradict the figures recorded in BTBs. The BTBs show only 1% of RBC units were discarded (waste) because the patient was not found, 20% of the units were discarded due to the patient passing away, 3% of the units were discarded due to changes in Hb level, and 5% of units were discarded due to the patient being transferred to another hospital ward. There appears to be a misalignment between the data recorded in the BTB and the understanding of hospital staff, as seen in the responses from the ESQ.

32% of the participants agreed that the 'frequency' of cancellations was due to patients not giving consent to a blood transfusion. However, this was never recorded as a reason in the BTB. It was, however, recorded in BTBs that 6% of RBC units ordered and received were discarded due to patients refusing a blood transfusion. The figure was supported by the responses of 24% of the participants in the EQS. Based on the process mapping, this result is surprising as the treating doctor requires the patient's consent before ordering blood. A reason for wastage being patients refusing blood transfusions makes sense in the context of understanding that blood is ordered before patients' consent is obtained.

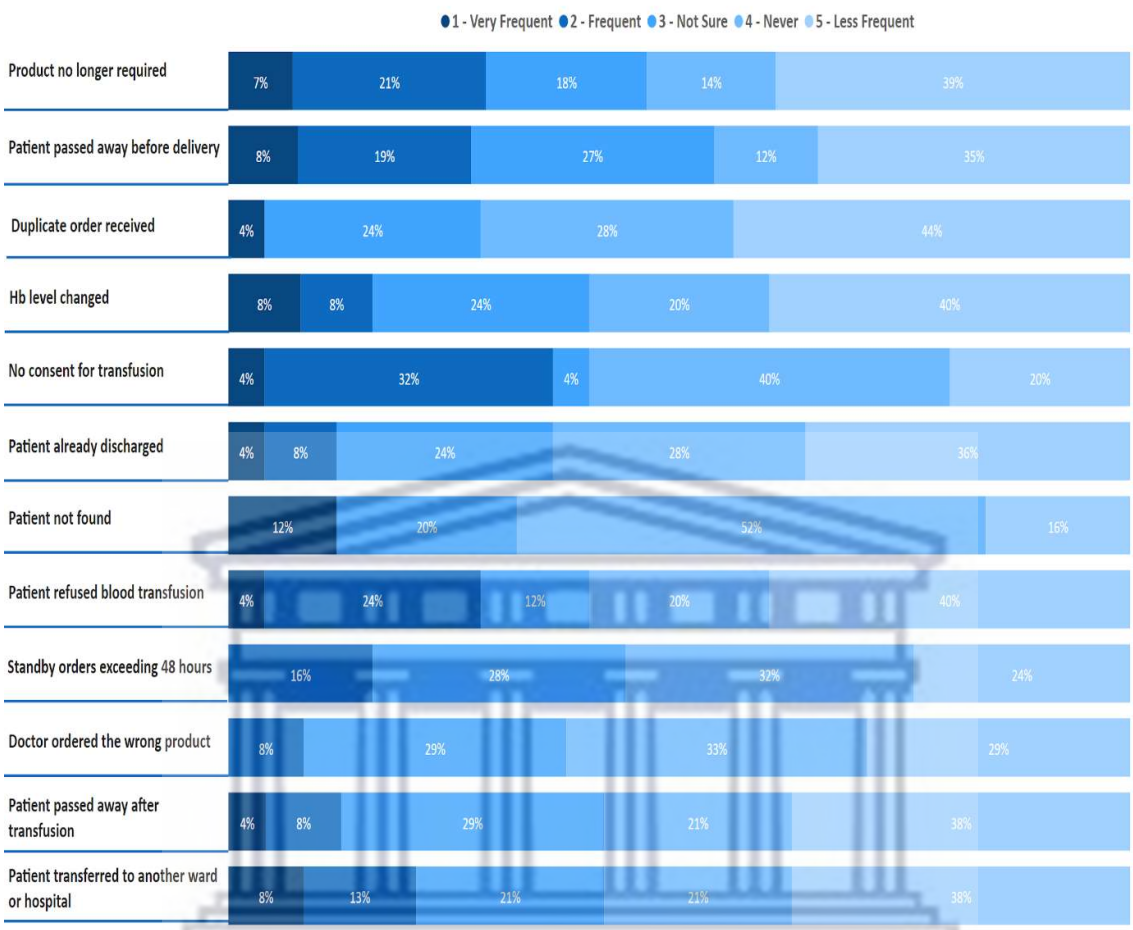

Figure 17: Reasons for unused RBC units (Question 7)

While 16% of participants agreed that standby orders exceeding 48 hours were a frequent reason for not using RBC orders, the BTB record did not support this response. **Table 6**, discussed in Section 2 above, summarises the responses from the EQS and BTB records.

Table 7 below incorporates the responses from EQS question 7 with the inputs from **Table 6** to explain the impact of the current process on blood wastage. The reasons for blood being discarded are considered together with the frequency of each reason occurring. Several contradictions were highlighted in the results when comparing the BTB data and the data obtained from the EQS. BTB data suggest that most RBC units are discarded because patients are discharged or passed away before transfusion. ESQ respondents agreed that patients not found is a significant reason for discarding RBC units.

Table 7: Reasons for discarding blood based on ESQ responses and process stages

#	Reason	Total %	Stages in the Process indicated in Figures 8 and 9	EQS Responses - % of Participants (frequency)
1	Patient discharged	24%	D11, E11, D12, E12	4%
2	Patient passed away	20%	D11, D12	12%
3	Refusal of blood	6%	A11, A12	4%
4	Patient transferred	5%	J11, J12	8%
5	Patient reaction	5%	J11, J12	8%
6	Hb changed	3%	B11, B12	8%
7	Patient not found	1%	A11, A12	12%

4.7.4 Traceability of blood products in hospitals

As shown in **Figure 18,** 36% of the participants strongly agreed that their ward or hospital has a system to return all unused blood products to the nearest blood bank. However, in the analysis of BTB data, Kalafong Hospital was found to have less than 5% of unused RBC returned to the blood bank, contradicting the survey results. Furthermore, the SANBS blood waste report indicated that less than 5% of RBC units were returned for incineration. The ESQ responses also showed that 14% of the participants strongly agreed with having regular audit checks on their wards to ensure that all unused blood products were returned to SANBS.

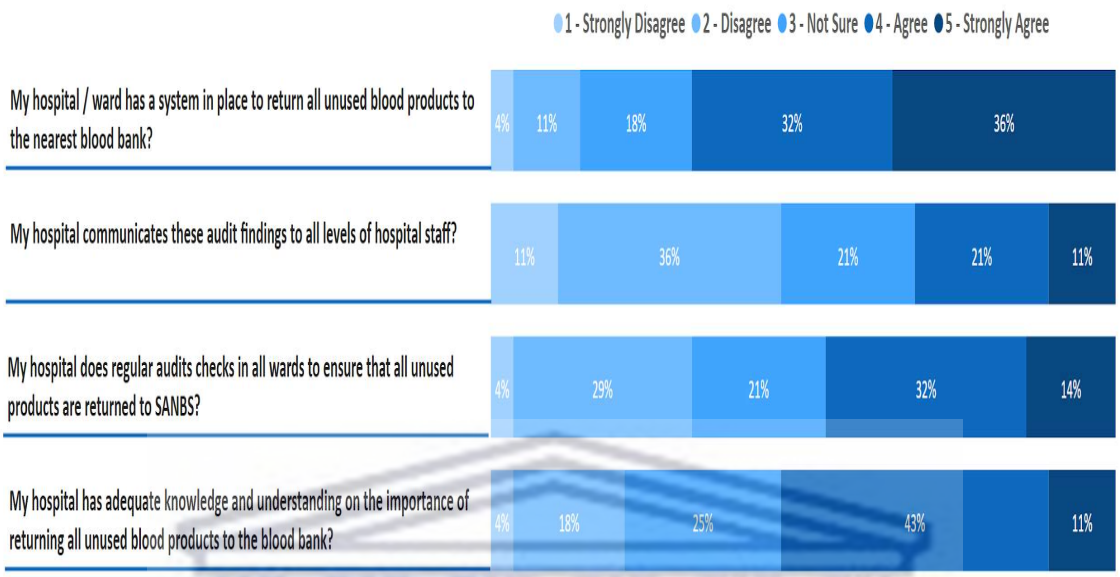

Figure 18: Traceability of blood (Question 8)

Figure 18 shows that 11% of the participants perceived that their hospital or ward had adequate knowledge and understanding of the importance of returning unused blood to the blood bank and that the audit findings were communicated. The information found in the BTBs, however, indicated the opposite. As seen in the BTB data, 71% of the RBC units could not be located, resulting in higher waste due to the limited traceability of blood products.

4.7.5 Patient blood management infrastructure for hospitals

In the section above, it is shown that there is a direct link between the number of RBC units ordered for the first transfusion and the location of the blood bank. During process mapping, hospitals with an on-site blood bank were found to adhere to the one-unit policy for the first transfusion, and there was no need for a clinical evaluation. As shown in **Figure 19**, the majority of ESQ participants (53%) agreed or strongly agreed that the time needed to transport blood products affects the ability of a ward or hospital to deliver blood products to a patient. Meanwhile, 71% of respondents agreed or strongly agreed that their hospital has adequate logistics to allow doctors to access blood products. The process is critical in determining whether unused blood products are returned to blood banks.

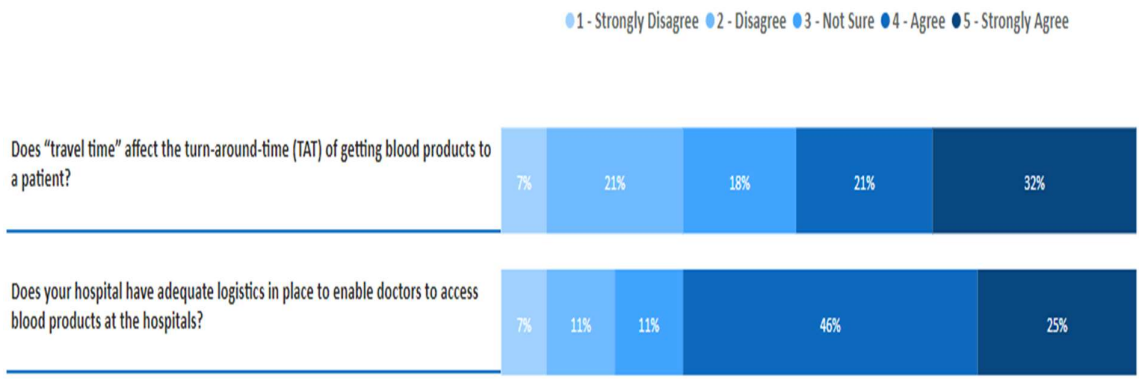

Figure 19: Knowledge of blood logistics (Question 6)

Most respondents felt that the absence of logistics processes to guide the transport of blood products creates a challenge that leads to a higher-than-average volume of RBC being ordered for the first transfusion by hospitals without on-site blood banks. The same effect was observed during hospital visits.

4.7.6 Patient Blood Management Policy

As shown in **Figure 20,** 83% of the survey participants agreed or strongly agreed that their hospitals have policies to guide the decision-making process when ordering blood products. However, the finding is not supported by any data collected from BTBs or SANBS. The high level of blood waste discussed in Section 4.5 occurs in all four selected hospitals. This problem is compounded by inconsistent reporting in the same hospital wards. During hospital visits, the nursing staff needed to indicate whether a PBM policy was in place, which would have helped to ensure that consistent data recorded was in the BTB.

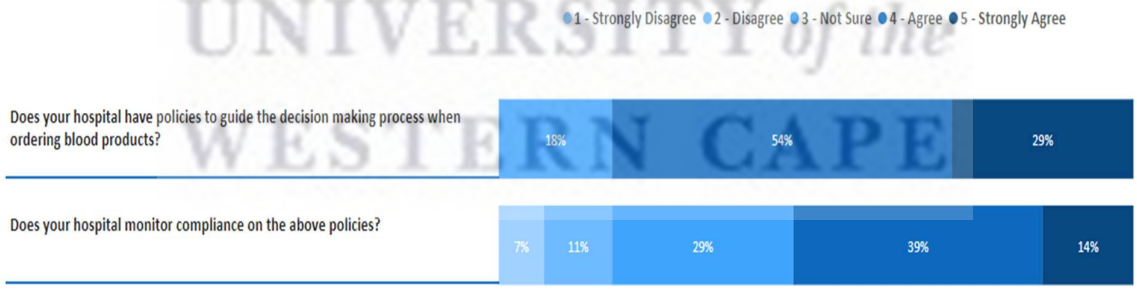

Figure 20: Blood logistics processes and policy (Question 5)

39% of the participants also agreed that their hospital or ward monitors the compliance of the policies designated for the decision-making process when ordering blood products. These results are not supported by data derived from documentation.

4.8 Conclusion

The findings discussed in this section have established the link between hospitals with a blood bank and the types of logistic methods that can be implemented. South Africa requires the tracing of blood products (National Health Act, 2003). Recording accurate information makes it possible to track and trace blood products and provides accountability for RBC units ordered by hospitals. Accurate information delivery and the standardised collection of data fields will impact how doctors and nurses account for the blood products used in their wards. WHO and SANBS provide guidelines on the fields required for blood transactions; this has been adopted in other countries similar to South Africa in delivering public health care services.

Data analysis has provided an understanding of the barriers in the RL process of blood products, mapping the process from PHFs to on-site and remote blood banks and highlighting drivers of the waste of blood products. The study's key finding is that many blood products, such as RBC, end up in landfills without being recorded (medically or administratively) as waste. This finding was supported by an analysis of BTBs and patient clinical records demonstrating that many RBC units were not recorded. The understanding of reasons for blood product waste varied between documented data analysis and ESQ results. According to the analysis of BTB and SANBS record data, the critical drivers of blood product wastage are that the patient was discharged before transfusion (found in the D11, E11, D12, and E12 of the process stages), the patient passed away before the delivery of blood required for transfusion (found in the D11 and D12 of the process stages), the patient refused a blood transfusion (found in the A11 and A12 of the process stages), the patient was transferred or not found (found in the J11, J12, A11, and A12 of the process stages) and that there were changes in the Hb level of the patient (found in the B11 and B12 of the process stages).

In contrast, ESQ participants suggested that the main drivers of waste were patients not being found, patients passing away, transfers, transfusion blood reactions, and changes in the Hb level. Overall analysis of the study has shown that the factors driving the waste are poor communication, ineffective administrative and clinical processes, too many manual paper-based processes, inadequate logistics processes, and lack of standardisation. Based on these research findings, the extent of RBC units wasted has been established, and processes mapped to understand how the waste is generated and the causal effects thereof. It must be noted that this study provides only an administrative perspective on the problem. More research is necessary to establish the correlation between administrative and clinical perspectives and their respective objectives, better to comprehend the implications of results from both views.

The study was limited to the use of RBC units. However, establishing the extent of waste generated as a variable allowed the model to measure the possible potential impact of technology on the reverse processing of blood products and identify possible logistic methods. This study clearly illustrates the relationship between the consumption of blood products and the rate of waste generated without considering the level of care and the hospital bed. Two questions are raised regarding the effects of the 'hospital bed' capacity: a) is it a factor in determining the amount of waste created? and b) is it a determining factor in implementing RL methods for blood products? More research is required to understand the relationship between bed capacity and possible waste of blood products. The research conclusion based on data analysis suggests that technology and sound logistic methods will impact the RL of blood products.

5. Conclusion

The concluding chapter of this study encapsulates and summarises the critical findings, both in terms of academic and practical significance, while acknowledging the research's inherent limitations and offering valuable recommendations for future exploration.

5.1 Research questions and objectives

The research aimed to understand the impact of technology on the RL of blood products in public hospitals. The aim was achieved by answering the following research questions:

a) What is the current RL process of blood from PHFs to on-site blood banks (managed by SANBS)?
b) What are the barriers in the RL process of blood from PHFs to blood banks?
c) What are the key drivers attributing to the waste of blood products? and
d) What technological solution can be implemented in PHFs for patient blood management?

5.1.1 Mapping Logistics Model

Concerning the first question, concerning 'mapping RL of blood products', the study identified two key processes used to order blood products in public hospitals. The first process was based on logistics for orders placed in hospitals with a blood bank on site, and the second process was for orders placed in hospitals with a remote blood bank. Each process followed a similar clinical path to assess the need for blood transfusion for the patient and had its unique complexity. Hospitals with on-site blood banks can more easily comply with regulations and SOPs on the handling and processing of blood products. In contrast, hospitals with remote blood banks struggle to order the single blood units recommended for initial transfusions. Hospitals with remote blood banks were more likely to run short of blood products than hospitals with on-site blood banks. A simplified RL process was discussed, and a conceptual framework was proposed to address the inconsistencies. The results indicated a higher volume of blood units wasted in hospitals with remote blood banks. However, the results were inconsistent since there was also a significant waste of blood units in hospitals with on-site blood banks. A closer look revealed that poor communication between nurses and doctors related significantly to issues in managing blood ordering, consistent monitoring of SOPs, and adherence to regulations of biomedical products.

5.1.2 Barriers in the logistics process of blood products

In response to the second question about 'barriers to RL', the research results indicated that the absence of logistic methods in the processing of blood products appears to lead to poor product handling, unmanageable logistics processes, and a lack of accountability. The findings further suggest that many blood products, such as red blood cells, end up in landfills without being recorded (medically and administratively) as waste. The finding was prevalent at all hospitals selected for the study.

For researchers, the results provide significant insight into the type of future studies needed to understand the forward and reverse logistics of blood products for public healthcare. The proposed conceptual framework will require further research on the cost and time required for implementation.

For administrators, the results provide insights into key barriers to the basic logistics processes of blood products in public hospitals. An implementation plan driven by GDoH norms and standards can be informed by the barriers identified in the study to ensure that correct logistics challenges are addressed.

5.1.3 Drivers of reverse logistics and attributing to the waste of blood products

Answering the third question, on 'rivers to RL', it is essential to acknowledge that preserving blood as a scarce resource is mandatory in delivering healthcare services. The logistics and packaging of blood products become essential in achieving this requirement. The research discussed logistics methods, such as milk run and just-in-time, as potential alternatives for the healthcare system to handle and process blood products. These methods can reduce the uncertainty associated with the availability of blood, reduce repetitive orders, and improve record-keeping.

The findings provide administrators with an opportunity to address the identified key drivers. The adoption of critical logistics methods will require the development of new SOPs and reengineering of the processes in all hospitals. Infrastructure adjustment to support hospitals with remote blood banks will be required; packing or the use of the BRB system must be prioritised to extend the life-cycle of blood products, as the repositioning of Patient Blood Management Committees plays a critical role in monitoring and managing the use of blood products.

For researchers, the findings provide insights into future research needed to establish the impact of RL drivers across the individual level of care and to deep dive into each specific driver. The volume of wasted units identified in the study provides a baseline that can be used to measure future interventions (clinical and administrative) that aim to reduce or propose mitigating alternatives for the preservation of blood products. Another academic opportunity illuminated by the study is the need to review the legislative prescripts used to control and manage the use of biomedical products in SA. The findings show that existing prescripts are ineffective in monitoring and guiding health workers in managing products of this nature. Future studies must provide policymakers with information on how these gaps can be addressed to make them more effective and efficient.

5.1.4 Proposed technology to automate the logistics of blood products

One of the central aspects that demand attention is the evaluation of technological solutions for addressing the implications of information technology on the reverse logistics of blood within public healthcare facilities in Gauteng. This facet of the research necessitates greater clarity to align more effectively with the overarching excellence expected of this dissertation. In light of this, a deeper and more comprehensive examination of the characteristics of the technological solution's impact on blood logistics is warranted. By achieving this level of granularity, the research can contribute more substantially to the academic discourse surrounding healthcare logistics and technology management. Answering the last question, to 'propose technology to automate the logistics of blood products', creating an electronic health record and adopting technology in healthcare is expanding to reduce cost and improve healthcare quality. Therefore, gaps in technology and data collected in healthcare settings become barriers to clinical transformation (Sensmeier, 2011). Technology is the key to information transformation and, if implemented correctly, can lead to improved quality of care, reduce medical costs and errors, and decrease the complexity inherent in the medical field (Bigus et al., 2011). GDoH is

implementing an HIS using the electronic medical adoption model (Ayat & Sharifi, 2016; Ayat, Sharifi & Jahanbakhsh, 2017) as a road map for digital transformation. The implementation of technology with the support of doctors, nurses, and hospital management will be a step in the right direction. The implementation will also require the standardisation of processes to manage and guide the processing and handling of blood products.

5.2 Academic contribution to the research

The results open the door for future research on the impact of such systems (logistics, IT, and HIE) on public and private healthcare partnerships. The change and adoption required to implement such systems would provide a window of opportunity for research-specific impacts and the skill sets required to execute and maintain high-tech healthcare environments. The most critical challenges to digital transformation service delivery involve people, processes, and technology (Bigus et al., 2011). People factors deal with changes in mindset and attitude, organisational culture, and leadership, while processes deal with understanding the complexity of tasks, process reengineering, and barriers. Finally, technology deals with system changes, automation, and digitisation and can solve complex problems in healthcare that were previously thought to be too intractable by 1) providing timely and detailed information to multiple medical specialities; 2) enabling the delivery of care across multiple healthcare specialities and levels of care; 3) enabling tracking of patients with known comorbidities; 4) detecting and recording adverse events related to drug reactions; 5) providing epidemiology data to track the spread of epidemics; and 6) helping to provide best treatment alternatives for communicable diseases.

5.3 Practical contribution and recommendations of the research

HIS, including HIE and the PACS, is the fundamental building block to creating an integrated ecosystem, unifying internal and external information systems. The HIS system can be integrated with other systems, such as SANBS, National Health Laboratory Services (NHLS), Department of Home Affairs (HA), supply chain and logistics systems, and medical service providers. Benefits to be accrued with the integrations include streamlined data exchange between GDoH and other providers throughout the value chain, reduced duplication of patient demographic data, improved patient waiting times, improved data accuracy, and a contribution to the long-anticipated reduction in paper patient records. Additional benefits include the ability to track blood orders, monitor utilisation, reduce waste, and ensure that the correct clinical data are accessible by the right doctor or nurse at the right time, regardless of time and geographical settings.

5.4 Research limitations

Simon & Goes (2012) state that research limitations are beyond the researcher's control and affect the result of the research. This study encountered several limitations. The collection of records required for the study was not standardised, resulting in different data-cleaning processes and analyses for each hospital. It was expected that the selected hospitals would provide different levels of care, but the main limitation was the use of various cleaning tools and processes. However, after cleaning and processing, the data output was subjected to similar analysis for all hospitals. As a result of COVID-19, data collection and verification were also constrained due to the time allowed to be spent at each hospital. The constraint could not be mitigated, as the choice of study environment required hospital visits during the COVID-19 pandemic. The methodology and design of the study used an observation protocol and an electronic questionnaire to collect primary data. Still, hospital staff time

was a limiting factor for both approaches and nursing personnel in similar wards were found to perform different tasks. The interpretation of the research findings cannot be generalised and made uniformly applicable to each hospital. Future studies must focus on each specific level of healthcare to address the methodology challenges experienced during this research. Conducting further studies outside the constraints of a pandemic would likely improve the conditions for data collection, data quality, and data verification and allow more extended interaction with nurses and doctors. The sampled participants were health workers, and there was no better time to interact with them due to the shortage of staff created by the pandemic, which resulted in fewer participants during the observation protocol. The shortage could have been a factor in the information received from nurses being found to contradict doctors' statements. This resulted in the poor credibility, accuracy and quality of the information collected on blood transfusion activities. During the data collection stage of the research, in addition to limitations, it was found that some of the challenges and barriers that result in blood waste required medical interventions, such as using the blood Hb level to decide whether a blood transfusion was required. However, the study was not designed to touch on medical-related findings or discussions. The study's recommendations were heavily influenced by a focus on technology and logistics, potentially overlooking other key factors. However, the results of this study can be used to inform future research and improve blood product management, reducing waste and assessing the potential for clinical interventions.

Finally, the study focused solely on public hospitals, which became a limitation, as it was found that blood management processes used to manage and prevent blood waste in the private health sector were conducted differently. If the scope of the research had covered the private health sector, it would have allowed a direct comparison of public and private processes to assess efficiency and effectiveness. Future studies could focus on similar research to further evaluate the private and public health sectors.

5.5 Research recommendations

The study's multifaceted approach to researching the impact of technology on the reverse logistics of blood products in public hospitals has generated numerous insights and yielded practical recommendations.

For researchers, focus is needed to understand the effort required to implement technology and its impact on service delivery. Using the HIMMS electronic medical adoption model has shown promising results in high-income countries such as the US, reducing costs and improving the quality of clinical transformation (Sensmeier, 2011). A better understanding of how such models would perform in middle-income countries like South Africa is required. Technology interrupts environments during implementation, and such interruptions are yet to be studied in a healthcare setting to understand impact and mitigation. Finally, the consideration of logistics methods and principles is in the early stages of public healthcare, and the framework discussed in the study paves the way for implementation assessments where the budget is limited.

For administrators, digital transformation in healthcare is still in its infancy. It requires policy changes to allow more industry role players to enter with cheaper and more reliable technological solutions. This study has provided a detailed view of the challenges linked to biomedical products such as blood and proposed how technology can address some of these challenges. However, this study does not claim to have answered every challenge related to the handling and processing blood. Further operational research and public engagements will require policymakers to make changes that will benefit and improve healthcare delivery.

In closing, it should be noted that the GDoH has been seen to make strides in investments toward digital transformation and the modernisation of business processes to improve and digitise healthcare services throughout the province (GPG, 2019). As part of Growing Gauteng Together (GGT) 2030, the province anticipates seeing the benefits of the above initiatives within the current Medium-Term Expenditure Framework (MTEF).

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7. Annexures

7.1 Annexure A: Description of data labels and formatting

As outlined in the data collection section, the secondary data included information on the total number of blood product orders, invoiced quantity, invoice cost, the ordering hospital, the specific ward within the hospital that placed the order, and the type of product that was ordered, etc., from January 2020 to December 2021. Six hundred fourteen thousand rows of data were received, with 20 columns, ranging from Material, UnloadPt, ShiptoParty, Reference Document, Sold-To Party, Billing Document, Month, Age, and Invcd. Qty, Invcd. Qty, Dr Name, Hsp Fin St, Hos.Num, ICD10 Code, Net value, Net value, Gr.inv.sls, Gr.inv.sls, Name, Sales, Sales, **Table 7** summarises the changes made to the data for analysis preparation for this study.

Table 8: Population sampling for the study

Original Column Name	Changes Made
Material	Product Description
UnloadPt ShiptoParty	Ward Description
Reference Document	Reference Document
Sold-To Party	Facility Description
Billing Document	Billing Document
Month	Month
Age	**Deleted**
Invcd. qty	Invcd. qty
Invcd. qty	Invcd. qty
Dr Name	**Deleted**
Hsp Fin St	Hsp Fin St
Hos.Num	**Deleted**
ICD10 Code	ICD10 Code
Net value	Net value
Net value	Net value
Gr.inv.sls	Gr.inv.sls
Gr.inv.sls	Gr.inv.sls
Name	**Deleted**
Sales	Sales
Sales	Sales

Four of the 20 columns (age, Dr, name, Hos. Num and name) contained identifiable information and were subsequently removed to protect the identity of the doctor and patient involved. The preliminary analysis focused on the four hospitals n = 4: Charlotte Maxeke Hospital, Kalafong Hospital, Kopanong Hospital, and Edenvale Hospital. The objective was to establish a product and quantity baseline between January 2020 and December 2021 for the hospitals identified for the research study. Since the study focuses only on red blood cells (vein transfusion), the products were identified through a discussion with the GDoH head office personnel

responsible for generating reports. Tables 4 and 5, respectively, show the total number of orders per hospital of interest and the type of product selection.

7.2 Annexure B: Observation Protocol

Program/Session Observation Protocol

Program Name:
Observer's Name:
Date: _____ Time Observation Began: _____ Time Ended:

Before the observation begins, briefly describe in #1 below, what you expect to be observing and why you have selected it.

1. Subject of the Observation.

The observation will record the ordering blood products by healthcare workers (Doctors and Nurses) from a Public Healthcare facility (Charlotte Maxeke Academic Hospital) in the Gauteng Department of Health. The process will be mapped as blood products are ordered from South African Blood Service's onsite blood bank.

2. *At the very beginning of the observation, the researcher will describe* (hospital name, department, number of units ordered, time taken for the units to be delivered, transportation of the units, and forms completed) *the setting, and note any changes in setting as the observation proceeds. Also, note how the session begins.*

3. The researcher will describe how the session begins. (who is present, what exactly was said at the beginning)

4. Describe the chronology of events in 15-minute intervals.

15 Min.	
30 Min.	
45 Min.	
60+	

5. Describe the interactions that take place during the observation.
5A. Who is interacting?

Doctors, Nurses,
Administrators,
Ward Clerks,
SANBS Admin

5B. How do they interact? Describe 1 or 2 examples.

5C. Are there any changes in interaction during the observations?

6. Describe how decisions are made during the observation period (by answering the following questions)

6A. Who makes decisions?

Doctors, Ward Clerks, Nurses, Administrators, SANBS Admin

6B. How are decisions communicated? (e.g., written, verbal,).

6C. Document examples of decisions that are made during the observation. *(Be sure to record who is making the decision.)*

7. Describe Nonverbal communication (How do participants get attention? How much do they fidget, move around? How do participants: physically place themselves in the setting?)

8. Describe program activities and participant behaviour's (i.e., what's happening during the session and how participants respond).

9. How did participants respond or react to what was happening with the program during the observation? Roughly what proportion (some, most, all) are actively engaged?

10. How does the program end? (What are the signals that the full circle of ordering of blood activity is ending? Who is present, what is said, how do participants react, how is the completion of this activity related to other activities?

7.3 Annexure C: Electronic Survey Questionnaire

Patient Blood Management Questionnaire

* Required

Research Project Information Sheet: Electronic Questionnaire

6/24/2021

1. What is this study about?

My name is Patrick Sello, a student at the University of the Western Cape (South Africa) pursuing a MCom Information Management - E-LOGISTICS. I am conducting a study to investigate the Impact of Information Technology on Reverse Logistics of Blood in Public Healthcare Facilities: The Case of the Gauteng Department of Health. This study is solely for academic purposes. However, the results of this research may also be shared with the Gauteng Department of Health (GDoH) and South African National Blood Services (SANBS).

What will I be asked to do if I agree to participate?
If you agree to participate in this research project, you will be asked to respond to a number of structured questions. This should take approximately 10 minutes. If you do not want to answer any question, you do not have to.

Would my participation in this study be kept confidential?
You are not required to provide any personal details, such as your name, address or identity number. All other details such as your age, education, employment status etc is therefore anonymous.

What are the risks of this research?
There are no known risks associated with participating in this research process. This research will not expose you to any harm as a result of your participation.

What are the benefits of this research?
The outcomes of this study will identify factors affecting the reverse logistics process of blood products in GDoH Public Healthcare Facilities (PHFs) that ultimately result in blood wastage and shortage. It is anticipated that dealing with these factors will reduce costs associated with blood wastage, lower mortality rates, reduce hospital stays, improve bed availability, and lead to better monitoring of Patient Blood Management (PBM). The cost-saving benefits will be realised over time and redirected to service other needs in improving patient quality of care. The recommended technology solution will provide GDoH with the opportunity to digitise and automate the PBM process, with benefits ranging from instant availability of information to improved data analysis, Internet of Things (IoT) opportunities and data-driven decision making.

Do I have to be in this research and may I stop participating at any time?
Your participation in this questionnaire is completely and entirely voluntary. You may choose not to take part
at all. If you decide to participate in this questionnaire, you may stop participating at any time.

What if I have questions?
If you have any questions feel free to contact the study leader:

Contact details of project leader (study supervisor)
Name: Dr James Kariuki Njenga
6/24/2021 University of the Western Cape, Department of Information Systems
Tel: (0) 2721 959 3680

Email: jkariuki@uwc.ac.za (mailto:jkariuki@uwc.ac.za)

Contact details of student
Name: Patrick Sello
Telephone: 082 338 5961
Email: 3919362@myuwc.ac.za (mailto:3919362@myuwc.ac.za)

NOTE: This research project has received ethical approval from the Humanities & Social Sciences Research Ethics Committee of the University of the Western Cape, Tel. 021 959 4111, email: research-ethics@uwc.ac.za (mailto:research-ethics@uwc.ac.za) *
I confirm that I have read and understand the information sheet explaining the above research project and I have had the opportunity to ask questions about the project.

○ Yes
○ No

6/24/2021

2. Do you participate in the ordering or processing of blood products in your facility? *

○ Yes
○ No
○ Maybe

3. What is your role in the hospital *

○ Medical Doctor
○ Nurse
○ Ward Clerk
○ Patient Administrator
○ Head of Department (HoD) in surgery and trauma
○ Supply Chain Management Administrator
○ Administrators (SANBS)
○ Haematologist
○ Blood Management Committee Member

4. Patient Blood Management ordering of blood products *

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Does more than 60% of your patients require 1 units of red cells for their first transfusion – without the need of clinical assessment?	○	○	○	○	○
Does more than 40% of your patients require 2 units of red cells for their first transfusion – without the need of clinical assessment between units?	○	○	○	○	○
Does more than 10% your patients require ≥3 units for their first transfusion – without the need of clinical assessment between units.	○	○	○	○	○
Does the hospital follow a Maximum Surgical Blood Ordering Schedule (MSBOS) to guide junior doctors on ordering requirements?	○	○	○	○	○
Does the hospital have a Massive Transfusion Protocol (MTP) and Massive Transfusion (MT) arrangement in place with the bloodbank?	○	○	○	○	○
Does the hospital utilize and promote the use of a blood on returnable basis (BRB) system?	○	○	○	○	○

6/24/2021

5. Patient Blood Management Policy *

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Do policies exist to guide the decision making process when ordering blood products?	○	○	○	○	○
Is compliance to these policies monitored on a per-department level	○	○	○	○	○
Does a two-way discussion platform exist where the violations of policies are discussed with all requesting doctors?	○	○	○	○	○
Is the hospital benchmarking their practices against a similar entity?	○	○	○	○	○

6. Patient Blood Management Infrastructure (Hospital Facility) *

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Are adequate, fool-proof logistics in place to enable doctors to access blood products at off-site hospitals?	○	○	○	○	○
How does "travel time" affect the total turn-around-time (TAT) of getting a product to a patient at an off-site hospital?	○	○	○	○	○

6/24/2021

7. When blood products are requested and then cancelled, a crossmatch was performed and will be charged to the hospital. How frequent does your unit/facility cancel order based on the reasons listed? *

	Very Frequent	Frequent	Not Sure	Never	Less Frequent
Product not required	○	○	○	○	○
Product not collected	○	○	○	○	○
Standby orders exceeding 48 hours	○	○	○	○	○
Doctor ordered the wrong product	○	○	○	○	○
Duplicate order received	○	○	○	○	○
Doctor cancelled order	○	○	○	○	○
Patient already discharged	○	○	○	○	○
No consent for transfusion	○	○	○	○	○
Hb count was normal	○	○	○	○	○
Patient Passed Away before delivery	○	○	○	○	○
Patient Passed Away after transfusion	○	○	○	○	○

6/24/2021

8. Full traceability of all blood products is a legal requirement stipulated in the National Health Act. Only unused products that are returned to the bloodbank can be included in the SANBS statistics. *

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Does your hospital have adequate knowledge and understanding amongst all levels of hospitals staff on the importance of returning all unused blood products to the bloodbank?	○	○	○	○	○
Does the hospital have a system (uniform to all wards / departments) in place to return all unused products to the nearest bloodbank?	○	○	○	○	○
Is the monitoring of the system to return unused blood products?	○	○	○	○	○
Is the hospital doing regular unannounced audits / checks in all wards to ensure that all unused products are returned to SANBS?	○	○	○	○	○
Are these audit findings communicated to all levels of hospital staff?	○	○	○	○	○

7.4 Annexure D: UWC Ethical Clearance

UNIVERSITY of the WESTERN CAPE

60 YEARS of hope, action & knowledge

22 October 2021

Mr P Sello
Information Systems
Faculty of Economic and Management Sciences

Ethics Reference Number: BM21/10/2

Project Title: The impact of information technology on reverse logistics of blood in public healthcare facilities in the Gauteng Department of Health.

Approval Period: **22 October 2021 – 22 October 2024**

I hereby certify that the Biomedical Science Research Ethics Committee of the University of the Western Cape approved the scientific methodology and ethics of the above mentioned research project and the requested amendment to the project.

Any further amendments, extension or other modifications to the protocol must be submitted to the Ethics Committee for approval.

Please remember to submit a progress report annually by 30 November for the duration of the project.

For permission to conduct research using student and/or staff data or to distribute research surveys/questionnaires please apply via:
https://sites.google.com/uwc.ac.za/permissionresearch/home

The permission letter must then be submitted to BMREC for record keeping purposes.

The Committee must be informed of any serious adverse event and/or termination of the study.

Ms Patricia Josias
Research Ethics Committee Officer
University of the Western Cape

NHREC Registration Number: BMREC-130416-050

FROM HOPE TO ACTION THROUGH KNOWLEDGE.

7.5 Annexure E The Gauteng Department of Health Ethical Clearance

GAUTENG PROVINCE
HEALTH
REPUBLIC OF SOUTH AFRICA

Joburg
a world class African city

Research Committee of Johannesburg Health District

Enquiries: Prof S. Moosa | 0824466825 (WhatsApp) | shabir@profmoosa.com

DATE: 19th November 2021

ATT: Mr Patrick Sello

EMAIL: PAT.SELLO@GAUTENG.GOV.ZA

Dear Sir

STUDY TITLE: The Impact of Information Technology on Reverse Logistics of Blood in Public Healthcare Facilities: The Case of the Gauteng Department of Health

NHRD REF. NO.: GP_202107_049

OFFICIAL APPROVAL

The District Research Committee has reviewed your application. This letter serves as a final approval letter for this study.

The following conditions must be observed:

- The facilities in which the research will be conducted are listed below
- These facilities will be visited from: 2021/11/19 to 2022/11/18
- Participants' rights and confidentiality will be maintained all the time.
- Neither the District nor the facility will incur any additional cost for this study.
- No resources (Financial, material and human resources) from the above facilities will be used for the study.
- The study will comply with Publicly Financed Research and Development Act, 2008 (Act 51 of 2008) and its related Regulations.
- You will submit a copy (electronic and hard copy) of your final report. In addition, you will submit an annual progress report to the District Research Committee.
- If this is academic research then your supervisor and the University will ensure that these reports are being submitted timeously to the District Research Committee.
- The District must be acknowledged in all the reports/publications generated from the research and a copy of these reports/publications must be submitted to the District Research Committee.
- You will liaise with the manager/s listed below as relevant before initiating the study.

We reserve our right to withdraw our approval, if you breach any of the conditions mentioned above. Please feel free to contact us, if you have any further queries.

On behalf of the District Research Committee, we would like to thank you for choosing our District to conduct such an important study.

Regards,

Prof S. Moosa
Chairperson: District Research Committee
Johannesburg Health District
Date: 19th November 2021

List of Facilities Approved

- Edenvale Hospital

List of Managers

Sub District/ Hospital	Sub District Manager/ Area Manager	Contact No.	Cell phone	Email
ABCEF	Ms Lombuso Matlala	011 440 1259	082 307 0267	Lombuso.Matlala@gauteng.gov.za
D	Ms Maria Mazibuko	011 674 1200	082 781 9919	Maria.Mazibuko@gauteng.gov.za
G	Mr Peter Mathole	011 213 9603	072 483 6839	Peter.Mathole@gauteng.gov.za
CoJ A	Ms Nelly Shongwe	011 237 8010	082 467 9276	nellys@joburg.org.za
CoJ B	Ms Zanozuko Mbane	011 718 9656	082 551 5804	zanozukom@joburg.org.za
CoJ C	Mr Tebogo Motsepe	011 761 0200	084 655 5420	TebogoMot@joburg.org.za
CoJ D	Ms Busi Phiri	011 986 0164	082 467 9386	busip@joburg.org.za
CoJ E	Mr Vusi Mazibuko	011 582 1504	082 464 9547	VusiM@joburg.org.za
CoJ F	Mr M Monyamane	011 681 8130	082 467 9423	mathibem@joburg.org.za
CoJ G	Ms Olga Kruger	011 211 8936	083 286 0388	olgak@joburg.org.za

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GAUTENG PROVINCE
REPUBLIC OF SOUTH AFRICA

KALAFONG HOSPITAL
PRIVATE BAG X396
PRETORIA
0001

ENQUIRIES : MS PM MONYEPAO
TEL : 012 318 6995
EMAIL : Patricia.Monyepao@gauteng.gov.za
REF : KPTH /2022/January

TO: Mr P Sello

RE: PERMISSION TO CONDUCT RESEARCH

TITLE: THE IMPACT OF INFORMATION TECHNOLOGY ON REVERSE LOGISTICS OF BLOOD IN PUBLIC HEALTHCARE FACILITIES: THE CASE OF THE GAUTENG DEPARTMENT OF HEALTH.

Permission is hereby granted for the research to be conducted at **Kalafong Provincial Tertiary Hospital.** Please note that full approval will be granted on receipt of Ethics approval as well as the registration number from the NHRD.

This approval is given in accordance to the "Promotion of Access to Information Act. No 2 of 2000" and it is expected of each investigator to ensure that all patient personal information will be managed and kept safe in agreement to the act.

Please note that in addition to receiving approval from the hospital research committee, you are still required to arrange the logistics with the relevant departments. You are obliged to inform this committee in writing of any amendments made to this protocol. Importantly, you require full approval (not conditional approval) before data collection can commence.

Informed consent for participation of research subjects and collection of data remains the responsibility of the researcher.

The hospital reserves the right to revoke this consent to do research in the facility if any misconduct with regards to patient participation or inappropriate behavior on behalf of the researcher comes to light.

You are also required to submit your final report or summary of your findings and recommendations to the office of the Chief Executive Officer.

Ethics approval submitted: YES NO

Kind regards

Approved.

DR K.M HTWE
MEDICAL MANAGER
DATE: 23/02/2022

GAUTENG PROVINCIAL GOVERNMENT
Kalafong Provincial Tertiary Hospital
2022-02-23
P/Bag / Privaat X396 Pretoria 0001
SUPERINTENDENTS OFFICE

GAUTENG PROVINCE
HEALTH
REPUBLIC OF SOUTH AFRICA

CHARLOTTE MAXEKE JOHANNESBURG ACADEMIC HOSPITAL (CMJAH)
OFFICE OF THE SENIOR CLINICAL MANAGER

Enquiries: *Ms. TT Mahlangu*
Email: Thandi.Mahlangu4@gauteng.gov.za
Tel: *011 488 3365*
Ref: *1/7/2*

28 February 2022

GP_202107_049

Dear Patrick Sello

RE: FINAL APPROVAL OF STUDY

TITLE: THE IMPACT OF INFORMATION TECHNOLOGY ON REVERSE LOGISTICS OF BLOOD IN PUBLIC HEALTHCARE FACILITIES IN THE GAUTENG DEPARTMENT OF HEALTH
Permission is granted for you to conduct the above-mentioned study as described in your request provided:

1. Charlotte Maxeke Johannesburg Academic Hospital will not in any way incur or inherit costs as a result of the said study.
2. Your study shall not disrupt services at the study sites.
3. Strict confidentiality shall always be observed.
4. Informed consent shall be solicited from patients participating in your study.

Please liaise with the HOD and Unit Manager or Sister in charge to agree on the dates and time that would suit all parties.

Kindly forward this office with the results of your study on completion of the research.

Supported/~~Not Supported~~
Signed by:Jayshnna Punwasi
Signed at:2022-03-01 16:46:09 +02:00
Reason:Witnessing Jayshnna Punwasi

Dr J. Punwasi
Clinical Director

Approved/~~Not Approved~~

p.p
Ms. G Bogoshi
Chief Executive Officer
04/03/2022

GAUTENG PROVINCE
HEALTH
REPUBLIC OF SOUTH AFRICA

Gauteng Department of Health
Edenvale Regional Hospital
Enquiries: A.R Nemadzhilili
Telephones: 0113216193
E-mail: Rose.Nemadzhilili@gauteng.gov.za

Principal Investigators (PI)	Mr Patrick Sello
Title	The Impact of Information Technology on Reverse Logistics of Blood in Public Healthcare Facilities: The Case of the Gauteng Department of Health
Organization / Institution	University of the Western Cape
Contact Details	PAT.SELLO@GAUTENG.GOV.ZA
NHRD number	GP_202107_049
HREC protocol ref no.	BM21/10/2

This communication serves to acknowledge the receipt of your request to conduct a research study as stated above, as well as to grant you the permission to conduct that research study at Edenvale Regional Hospital. Before conducting a research, arrangements need to be made with the specific departments, that is: the clinical manager: Dr D Maluleke , 011 321 6082 and Medical Technologist: Ms N Idom 084 216 7265
The permission is granted in line with the following code of ethics /research.

- You need to bring the copy of official university ethical clearance certificate prior conducting the study.
- You need to bring the copy of (DRC) District research committee approval.
- You need to arrange with the specific and relevant departments where you will require the specific information prior conducting the research
- All the information obtained must be used for the purpose of the research
- The information will be utilized discreetly and confidentiality will be maintained always.
- There should be no financial implication to the hospital.
- There should be no interruption of daily provision of services.
- The collection of data will be the responsibility of the researcher.
- Kindly submit a copy of the final report after completion
- Kindly adhere to COVID 19 protocols accordingly.

Your understanding and co-operation in this regard is highly appreciated.

Ms. A. R Nemadzhilili: Human Resource Development

Date 25/01/2022

Recommended/not recommended

Dr. Z. G Zitha: Chief Executive Officer: Edenvale Regional Hospital

Date 25/01/2022

Approved/not approved