THE DYNAMICS OF SUPPLY CHAIN INTEGRATION: EMPIRICAL EVIDENCE FROM PUBLIC HEALTH SUPPLY CHAINS IN KADUNA STATE, NIGERIA

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

The Kaduna State supply chain transformation initiative aims to integrate all state-fragmented supply chains to improve medicine availability performance. Supply chain integration enables organisations to collaboratively work with medicine suppliers and customers to achieve cost savings and improve service delivery, lead times, and performance. This study empirically assesses public healthcare supply chains and builds a dynamic theory of integrated healthcare supply chains based on systems dynamics. Underpinned by systems engineering theory and the system dynamics integrative paradigm, this study used interplay paradigm crossing in a mixed-method multiple case study to measure the availability of medicines in five public healthcare supply chains and developed a dynamic hypothesis from the mental models of system actors to increase the Medicine Fill Rate (MFR). Constraints in each supply chain were analysed to understand the perception of the structure, feedbacks, and dynamic behaviours that drive medicine availability. A network conceptual model was used to design a three-tiered stock-and-flow model for an integrated supply chain. Policies for financial management, government funding, order management, and inventory management were developed and tested to achieve a 90% MFR.

The findings of this study show that the five supply chains can benefit from integration by forming strategic alliances with suppliers for pooled procurement. Sharing resources, risks, and benefits through the adoption of digital platforms to improve communication, visibility, and trust serves as a fulcrum for network integration. The use of supply chain finance and a performance-driven approach by the integrated network assists in breaking the capability and bailout trap of resource dependency on government funding. This study enriches the development of a dynamic theory of supply chain integration that will benefit managers, essential medicine stakeholders, donors, and policymakers by developing network-revolving fund model policies to reduce medicine stockouts and increase essential MFR for the treatment of diseases.

DECLARATION

This work has not been previously accepted in substance for any degree and is not concurrently submitted in candidature for any other degree.

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STATEMENT 1

This thesis is the result of my own investigation, except where stated otherwise. Other sources were acknowledged by footnotes, providing explicit references. Bibliography has been appended.

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STATEMENT 2

I hereby give consent for my thesis, if accepted, to be available for photocopying and for inter-library loans, and for the title and summary to be made available to outside organisations.

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DEDICATION

I dedicate this thesis to cherished individuals, whose unwavering support and encouragement have been my pillars of strength throughout this academic journey.

To my beloved husband Muhammad, your steadfast support and understanding have been my rock. Your encouragement has fuelled my determination and your belief in me has been a constant source of inspiration. This achievement is as much yours as it is mine.

To my dear children, Sauda, Zahra, and Humaira, your smiles, laughter, and love have been my motivations for the toughest days. Thank you for cheering on and standing by me through the highs and lows of this endeavour.

In loving memory of my late father, Alhaji Abdulmumin Abdulkadir, who departed during the course of this study. Your wisdom and encouragement echo in my heart, and I hope I have made you proud.

To my dearest mother, Hajiya Baida'u, you have been my guiding light and epitome of strength. Your sacrifices and unwavering beliefs about my abilities have made everything possible. This thesis is a tribute to your resilience and the values you have instilled in me.

With profound gratitude and love,

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ABBREVIATIONS

CO	Customer Orders
CPFR	Collaborative Planning, Forecasting, and Replenishment
CSCMP	Council of Supply Chain Management Professionals
DMNL	Dimensionless
DRF	Drug Revolving Fund
EMs	Essential Medicines
ERP	Enterprise Resource Planning
FEFO	First Expiry First Out
GHSCMM	Global Health Supply Chain Maturity Model
HF	Health Facility
HIV	Human Immunodeficiency Virus
ICT	Information and Communication and Technology
IoT	Internet of Things
ISC	Integrated Supply Chains
IS	Internal Staff
IT	Information Technology
MAP	Medicine Availability Performance
MD	Medicine Distributors
MFR	Medicine Fill Rate
MM	Medicine Manufacturers
MMPR	Mixed Method Phenomenological Research
NAFDAC	National Agency for Food, Drug, Administration and Control
NHIS	National Health Insurance Scheme
NT	Network Theory
PM	Performance Measurement
POD	Proof of Delivery
RACI	Responsible, Accountable, Consulted, and Informed Matrix
SDPs	Service Delivery Points
SP	Service Providers
SRH	Sexual and Reproductive Health
SOPs	Standard Operating Procedures
SC	Supply Chain
SCs	Supply Chains

SCI	Supply Chain Integration
SCM	Supply Chain Management
SCOR	Supply Chain Operations Reference model
SCP	Supply Chain Performance
SD	System Dynamics
TCE	Transaction Cost Economics
TSA	Treasury Single Account
SDGs	United Nations Sustainable Development Goals
VAN	Visibility and Analytics Network
WMS	Warehouse Management Software
WHO	World Health Organisation

1 INTRODUCTION

Since independence, Nigerian public services have undergone reforms to foster the effectiveness, efficiency, and responsiveness of the services (Ferlie *et al.*, 1996; Ogunrotifa, 2012) to deliver good governance to citizens. Extant literature suggests that some of the reforms have been successful, while others are debatable (Ogunrotifa, 2012), and more needs to be done to achieve service delivery excellence in Nigerian public service. The healthcare sector in Nigeria has benefited from donor and partner support in public health Supply Chains (SCs), these SCs are fragmented and vertical, and efforts have been made to integrate public health programs at the national level to achieve Goal Three of the United Nations Sustainable Development Goals (SDGs) (World Health Organisation, 2019). In March 2021, the federal government published and disseminated the National Health Products Supply Chain Strategy and Implementation Plan 2021-2025. The strategic plan aims to foster end-to-end visibility, leading to accountability and improved performance of the country's SCs by integrating fragmented SCs to reduce medicine waste and improve availability (Federal Ministry of Health, 2020). Healthcare is decentralised and managed by state and local governments. Most states do not have sufficient funds to manage their SCs; hence, they rely heavily on donor support. Stakeholders are yearning for the integration of fragmented SCs in the public health sector with the expected attendant benefits of increased Supply Chain Performance (SCP) through competitive advantage (Schoenherr and Swink, 2012) and the use of innovation to stay ahead of competition (Eldabi *et al.*, 2010). Although the essential medicine SCs are socially driven and do not profit from sales, ensuring that patients receive medicines during treatment is crucial through integration to attain the SDGs.

1.1 Research background

The Kaduna State government has been reforming its public service through the Public Service Revitalization and Renewal Programme launched in 2016. The healthcare sector has been improving through the public health Supply Chain (SC) transformation initiative. Transformations in healthcare can lead to unintended effects (Paina and Peters, 2011; Bigdeli *et al.*, 2012). Consequently, it is necessary to examine the transformation effect on improving Medicine Availability Performance (MAP). A transformation initiative was conducted to improve the efficient delivery of health supplies and provide system visibility to ease operational planning. Saving the lives of patients was the targeted outcome of essential medicine by increasing the medicine fill rates in hospitals. Establishing a performance culture to sustain achievements was critical for the integrated DRF program. Swanson *et al.* (2012)

stated the benefits of transforming healthcare systems from a system thinking perspective where the use of system thinking tools considers the whole system and the impact of policies on every aspect as compared to deploying target interventions which is inadequate for complex health systems. The Kaduna state has nine (9) SCs, and the need to integrate these SC systems into one public health SC that will eliminate waste and increase effectiveness and efficiency in the SC is critical. Eight of the nine SCs were vertical program SCs, whereas one of the SCs was managed by the state government for Essential Medicines (EMs). The state has taken the approach of owning its SC transformation which has led to a mature state of integration and collaboration with stakeholders to achieve a single integrated SC that is cost effective and delivers medicines to citizens. This study aims to clarify the effect of Supply Chain Integration (SCI) from a public health SC perspective. It seeks to develop a theory of SCI and how the integration of supply networks leads to an increased MAP from a system dynamics perspective.

Kaduna State along with thirty-six states of the Federation, including the Federal capital, have fragmented SCs. In 2016, The Kaduna State government embarked on a bold transformation of the public health SCs to integrate all nine fragmented SC into the state's One Public Health SC. The initiative is led by the government, working with multiple stakeholders to achieve the vision of the state. According to Chen *et al.* (2009), SC1 considers the interaction between external factors and the internal functions of an organisation, which leads to performance. SCI has been researched in various contexts globally and is becoming an area of interest in Nigeria's public health sector. This study focuses on the Drug Revolving Fund (DRF) essential medicine SC, which recovers the cost of medicines sold to patients with a markup. Hospitals across the primary, secondary, and tertiary care levels operate fragmented SCs, leading to expiries and wastage. The 2020 global coronavirus pandemic has shown how vulnerable healthcare SCs are compared with other businesses. At the height of the pandemic, all global SCs were shut down due to the weakest link which appeared to be the healthcare SCs. Therefore, it has become imperative to apply innovative SC solutions to solve healthcare problems. SCI is a novel solution used in SCs to minimise costs, improve lead times, and improve network performance (Kim *et al.*, 2014).

However, very few studies exist on SCI in Nigeria and at subnational levels. The struggle to integrate the five (5) public health programs is ongoing at the national level. At the same time, the essential medicine SC which takes care of the needs of most of the population, has not received any attention. In contrast, Kaduna State started with the essential medicine SC which serves the needs of most citizens to anchor the remaining eight (8) SCs. Stakeholders are divided and apprehensive about where to begin integration, considering the sensitive nature of healthcare, but everyone agrees on the need to integrate some or all SCs to improve service delivery, save costs, and improve the MAP.

1.2 Research key concepts

The concept of SCM can be explained using multiple theories, as it refers to the partnership between organisations to produce and deliver products to the customer at the best price. Studies have identified some of the theoretical lenses of SCM that include the principal-agent theory because of the interaction between independent entities. The end goal of making a profit aligns with the transaction cost analysis, where each organisation in the supply chain is trying to make a profit. On the other hand, network theory views supply chains as networks and presents an opportunity to explore the relational ties between organisations, while the resource-based view considers the resources owned by supply chain partners that can be combined to give competitive advantage (Halldórsson *et al*., 2015). SCI examines how a network of supply chains can improve SCP and reduce costs. SCI is believed to confer advantages to organisations that develop strategic relationships with their partners to perform better than competitors. Working together implies the need to combine resources to achieve a common goal among partners (Porter, 1980). Building partnerships calls for relational competencies to ensure the seamless implementation of supply chain strategies, as highlighted by Prajogo and Olhager's (2012) study, indicating that long-term relationships lead to improved organisational performance. The goal of SCI is to reduce costs and improve efficiency in the network, not just for a single organisation. In addition to building relationships, there is a need to ensure network efficiency to improve service delivery in healthcare supply chains (Provan and Milward, 1995). Although the resource-based view, relational theory, transaction cost economics, and network theory have contributed to SCI studies, these theories do not fully explain the system behaviours and feedback driving SCI policies that lead to improved SCP in healthcare supply chains. Although relational rents can be derived from strategic partnerships with supply chain partners to improve business operations (Prajogo and Olhager, 2012; Jiang and Zhao, 2014; Yeh *et al.*, 2020), performance improvement in the network extends beyond relational competencies to understanding the dynamics of SCI policy implementation and decision-making in the system. The complexity of healthcare systems necessitates the use of system engineering theory which has various viewpoints, such as the general systems theory which involves seeking commonalities between different systems (Bertalanffy, 1968). Another approach is Forrester's

(1968) dynamic theory for exploring the behaviour of complex systems over time. Hence, the nature of public healthcare as a complex system is better explained when systems engineering theory is used to develop an integrated system that explores the feedback dynamics and time delays that shape the decision making of system operators.

1.3 Research problem

The Kaduna public healthcare system is integrating the essential medicine DRF supply chain with other vertical programs. The DRF program provides medicines for the treatment of diseases for the majority of citizens. Although the DRF SC is synchronising the demand and supply planning of all essential medicines, hospitals in the state still experience essential medicine stockouts, making it difficult to treat patients and save lives. This situation is worrying to managers and stakeholders, as integration efforts to increase access to medicines for patients continue to fall below expectations. While medicine fill rates continue to decrease, medicines expiries increase, leading to the wastage of scarce resources. The expected benefits of integration include improved medicine availability and reduced wastage. Lack of performance management for system operators and fragmentation of medicine SCs have been highlighted as problems preventing medical access in public health SCs (Yadav, 2015). Furthermore, previous studies have underscored poor management practices in the Kaduna supply chain and called for more effective approaches to the provision of medicines (Mohammed *et al*., 2007). However, none of these studies have investigated the dynamics of SCI and its effect on essential medicine fill rates. The focus on SCs operation without considering customer-focused performance metrics is a research gap that this study aims to fill. Working with supply chain partners to deliver medicines to hospitals at the right time is critical for ensuring that prescriptions are filled when needed. As a systems engineering approach, SCI helps build SCs to observe feedback and delays in the DRF chain to achieve the desired performance output of improved medicine fill rates. To determine the level of integration that improves performance, managers must understand the behaviour over time after implementing integration practices and the use of key performance indicators to define the success or failure of their strategies. Understanding how the system works will shape future policies for integrating healthcare programs to become more effective. This study uses systems engineering theory to explore the integration of medicine suppliers and stakeholders in the DRF supply chain, which leads to increased medicine availability and prescription fill rates. The theoretical proposition will demonstrate the reasons behind the increase in medicine availability for supply chains that integrate with network partners and not just internal integration to improve medicine availability. This research also shows why the integration of some aspects alone was insufficient to improve the MAP. The essence of system engineering is to build more efficient SC systems. Hence, the central question in this study is how SCI practices improve patients' medicine fill rates. Hospital prescription fill rates, as performance indicators, are customer-facing and reflect the effectiveness of the medicine supply system. Supply chain integration of subsystems responsible for the delivery of products to end-users improves business competitiveness and performance. Performance in DRF supply chains was measured based on the availability of life-saving essential medicines. With the increase in integration, there is an expected increase in medicine availability. Thus, there is a need for research that explores the factors that contribute to medicine availability performance and the strategies that can be used to improve it. Specifically, this study examined the following research questions:

1. Does SCI improve medicine availability performance?
2. How does SCI increase the availability of essential medicines in SCs?
3. What type of medicine availability performance does integration improve in essential medicine SCs?
4. What are the factors that enable or inhibit the availability of essential medicine SCs?

This study is significant because it provides valuable insights into the relationship between SCI and medicine availability performance, which can be used to inform policies and programs aimed at increasing medicine availability performance in public health SCs. This study used a system dynamics approach to provide a comprehensive understanding of medicine availability performance in integrated public healthcare SCs. The specific objectives of this study are as follows:

1. To empirically investigate how SCI levels improve medicine availability performance.
2. To identify the integration viability of the identified SCs that could affect the availability of medicines
3. To develop a dynamic theory for integrating SCs using a computer simulation model.
4. To validate the dynamic theory to understand the enablers and barriers to medicine availability.

1.4 Justification of the study

Medicine stockouts are a fundamental problem in healthcare SCs worldwide that prevent countries from achieving Universal Health Coverage (UHC) (Perehudoff *et al*., 2019; Kiragu *et al*., 2022). Medicine availability is a major area of interest within the field of public health SCM, and various studies have highlighted the importance of the effective management of essential medicine SCs in saving lives and achieving positive health outcomes (Bateman, 2013; Bam *et al.*, 2017). Medicine stockouts in hospitals can lead to loss of life, necessitating calls for more research on collaboration between supply chain partners to increase medicine availability (Friday *et al.*, 2021). SCI is increasingly being recognised as a critical collaborative component in the management of healthcare SCs worldwide. Integrated SCs have been reported to demonstrate a better performance than fragmented chains. Integrating internal and external operations increases service delivery to patients and reduces the operational costs for all partners within the network (Stevens, 1989). Integration for improved performance is critical for public healthcare supply chains in developing economies, where governments are supported by donors and multilateral organisations to provide essential medicines (Sarley *et al*., 2017). First, the global post-pandemic economic recession increased the burden on healthcare supply chains and strained government and donor funding. Increasingly, developing countries find it difficult to fund the provision of essential medical supplies to their citizens (Lugada *et al*., 2022). Hence, government-owned medical supply chains have trouble paying for supply. Delays and difficulties in procuring medicines lead to medicine stockouts in hospitals, as suppliers are unable to fulfil hospital orders. Second, the drug revolving fund program implemented to ensure continuous funding for essential medicines has not solved the medicine stockout problem, as medicine fill rates are below 50 percent availability. The poor performance of essential medicine SCs impacts healthcare delivery because the majority of Kaduna citizens cannot access medicines in hospitals for critical care. The inadequate funding of public healthcare SCs and subsequent poor performance are setbacks for governments to achieve UHC. The use of the SCI strategy to reduce costs, waste, and improve medicine availability was introduced by the Kaduna state government in 2017 to increase coordination and collaboration with donors and SC partners. Thus, investigating the reasons for medicine stockouts is a continuing concern in public health SCM.

Recently, researchers have shown an increased interest in public healthcare SCI, underscoring the benefits of cost savings from integrating certain activities in SCs. However, Yadav *et al.* (2014) caution the integration of higher-level supply activities to avoid healthcare program failures (Yadav *et al.*, 2014). This raises the question of the level of integration that ensures availability of medicine. However, the benefits of SCI on patient-centric outcomes have been overlooked in previous studies, as emphasised by the call for widening the scope of systems studies to demonstrate benefits to patients and not just a focus on the workings of the SC (Settanni *et al.,* 2017). Fabbe-Costes and Jahre (2008) argue that extensive integration leads to diminishing performance, leading to calls for empirical studies. Although longstanding relationships have been reported to improve business outcomes (Prajogo and Olhager, 2012), another study reported higher costs of doing business and longer lead times as a result of the length of relationships (Bagchi *et al.*, 2005). Fawcett and Magnan (2002) also report complications arising from multiple supply chain relationships. To date, there is no consensus among researchers on the level of integration and the extent of relationships that can sustain performance. The impact of SCI on medicine fill rate remains unclear. This study bridges the identified gaps by examining the dynamics of SCI on patient-centric performance indicators of the MFR using system dynamics methods. The practical implication of this study is that it assists managers in healthcare supply chains to work closely with development partners to implement integration approaches that increase the supply of medicine to hospitals. This study also guides country governments, donors, multilateral organisations, and other funding organisations in channelling resources to support integration in areas with the greatest impact on medicine availability. Prudent investment in healthcare increases the quality of life of citizens and unlocks the economic benefits that facilitate the achievement of UHC and Sustainable Development Goals. Medicine manufacturers, distributors, and suppliers benefit from this study by leveraging building relationships with public health SCs to ensure the continuous availability of medicines. Strengthening collaboration with suppliers protects the system and builds the ability to withstand shocks and disruptions in supply. Sharing of resources and risks between SC partners saves costs and improves access to medicines for patients. The field of public health SCM benefits from this study by demonstrating the integration viabilities of healthcare SCs and their impact on fill rate performance. This study enriches the system dynamics theory of SCI and expands our understanding of how integrated networks can improve the MFR and patient satisfaction.

1.5 Scope of the study

While the effects of SCI in private companies have been well documented, its impact on public healthcare supply chains is poorly understood. This study aimed to determine the effects of SCI on the availability of medicine in public healthcare supply chains. The study scope is limited to five public SCs in Kaduna State with more than three years of operational experience in the essential medicine revolving fund program. The study covers the changes observed in integration over a period ranging from to 2017-2020. The management of the organisations was contacted to assign a gatekeeper to recruit participants for the group survey and in-depth interviews. Each DRF operational team was requested to complete a questionnaire to evaluate the baseline medicine availability performance and the status of operational activities within the SC. This was followed by in-depth interviews with experts to evoke causal statements of medicine stockouts and understand the dynamics of medicine availability.

1.6 Research originality

This thesis is unique in that Kaduna State has nine (9) parallel or vertical SCs. Essential medicine SCs are unable to meet the needs of providing medicines to citizens due to stockouts, high costs, and wastage (Akut *et al.*, 2016; Abdulkadir and Tafuri, 2017). The government and all stakeholders have identified SCI as key to providing medicines but are unsure of how to integrate SCs. Although stakeholders agree on the benefits of SCI in reducing costs and wastage, there is also a fear of losing the small gains of the current system. This research will contribute to the government's efforts to integrate health-sector SCs to achieve synergy, effectiveness, and efficiency through an SC strategy and implementation plan (Federal Ministry of Health, 2020). This study contributes to academic discourse on SCI. The novel dynamic theory from this research will empower policymakers, stakeholders, and healthcare managers to develop policies and strategies to integrate SCs for improved MAP that will lead to high service delivery to end-users. This research will save lives by reducing costs and wastage in the system and provide access to medicines.

1.7 Thesis structure

This thesis is organised into eight (8) chapters (Figure 1.1)

Chapter One - Introduction: This chapter introduces the research topic and provides the background and context of the study. Chapter one outlines the aims and objectives of the research and concludes with its originality and thesis structure.

Chapter Two - Literature Review and Analysis: This chapter focuses on an extensive review of the extant literature on the concepts of SCI and performance. Chapter Two highlights the gaps in the literature and the evolution of the concepts of integrated performance measurement.

This chapter also includes the conceptual framework of SCI and concludes with a theoretical framework.

Chapter Three - Research methodology: This chapter covers the philosophical and ontological foundations of this research. This section presents the research design.

Chapter Four - Case studies and performance measurement: This chapter presents the maturity model tools used to measure the performance of SCs. Performance and operational constraints hindering the availability of medicines in the case studies were determined.

Chapter Five - Case studies and dynamic feedback system: This chapter provides a detailed quotation analysis of in-depth interviews and introduces system dynamics causal loops diagramming to illuminate the system structure and dynamic feedback driving medicine availability and fill rate performance. The chapter concludes with a dynamic hypothesis and theory of medicine availability in integrated Supply Chains (ISC).

Chapter Six - Case study modelling and simulation: This chapter presents the model overview and boundaries in a stock and flow diagram of integrated SCs. Chapter six explores different policies that reduce medicine stockouts and enhance customer fulfilment.

Chapter Seven - Discussions of key findings: This chapter summarises the key findings of the study in relation to the aims and objectives of this study and the research questions. The chapter concludes by outlining how the key findings have been able to answer the research questions and meet research goals.

Chapter Eight - Conclusion and recommendations for future studies: This chapter concludes the thesis by outlining the outcomes and contributions of the study. This chapter also provides the limitations of the study, recommendations, and guidelines for future studies.

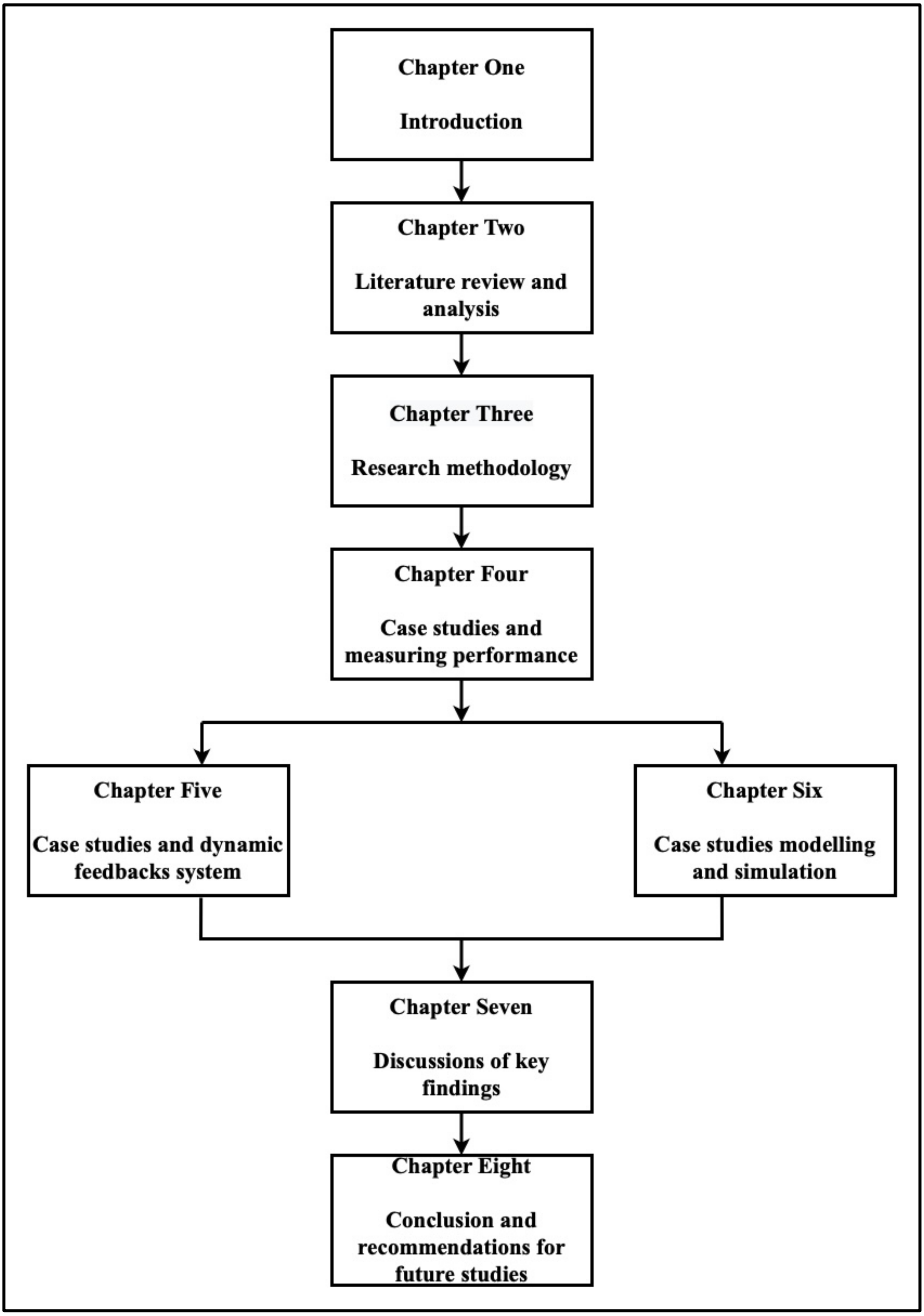


Figure 1.1: Thesis structure

2 LITERATURE REVIEW AND ANALYSIS

2.1 Introduction

This study was organised by conducting a literature review on supply chain management (SCM) with an emphasis on supply chain integration to achieve objectives 1 and 2 of this study and identify the gaps related to the concepts of SCI and SCP. This chapter details the outcomes of an extensive literature review of SCI and SCP. The concept and levels of SCI linked with SCP are presented together with the capabilities, enablers, and barriers to the integration of various SCs and the performance that can be achieved through integration. The chapter concludes with a focus on healthcare supply chains within the context of Kaduna State, and introduces system engineering theory and system dynamics as a methodology for assessing integration in public healthcare SCs. The outcome of the literature review led to the development of a conceptual framework that attempted to close the identified gaps (Figure 2.1).

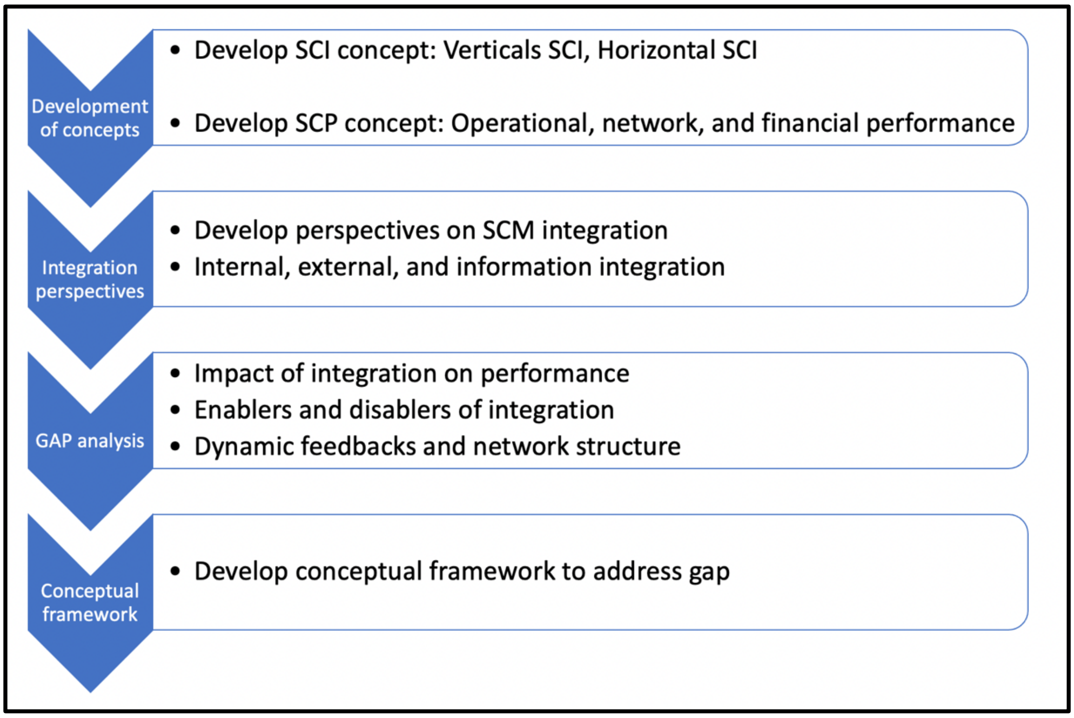


Figure 2.1: Process of literature review

2.2 Definition of concepts

Forrester's 1958 publication on industrial dynamics identified the importance of relationships between firms, suppliers, markets, and the ecosystem and serves as the basis for modern SCM (Forrester, 1958). Mentzer *et al.,* 2001 defined supply chain as "a set of three or more entities (organizations or individuals) directly involved in the upstream and downstream flows of products, services, finances, and/or information from a source to a customer". This study also identified three types of supply chains based on complexity: direct, extended, and ultimate SC (Figure 2.2). Direct SC is a basic structure involving a firm, supplier, and customer. Extended SCs involve complex relationships with tier 1 and tier 2 suppliers and customers. The ultimate SC involves all organisations operating downstream and upstream to obtain products for the customer (Mentzer *et al.*, 2001). According to Larson and Rogers (1998), SCM "is the coordination of activities, within and between vertically linked firms, for the purpose of serving end customers at a profit". This definition was based on the study of the growth of SCM from logistics which is mainly intra-organizational as opposed to the inter-organizational orientation of SCM. Conversely, the Council of Supply Chain Management Professionals states that "Supply Chain Management encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities. Importantly, it also includes coordination and collaboration with channel partners, such as suppliers, intermediaries, third-party service providers, and customers. In essence, SCM integrates supply and demand management within and across companies" (Gibson *et al.*, 2005). By contrast, this definition includes working with partners across networks. While the other definitions focused on the activities and collaboration among partners, supply chain management was defined by Christopher (2016) as "The management of upstream and downstream relationships with suppliers and customers in order to deliver superior customer value at less cost to the supply chain as a whole". Contrary to the first two definitions, Christopher considers the financial performance of an ISC. However, there appears to be a lack of consensus regarding the structure and definition of SCM.

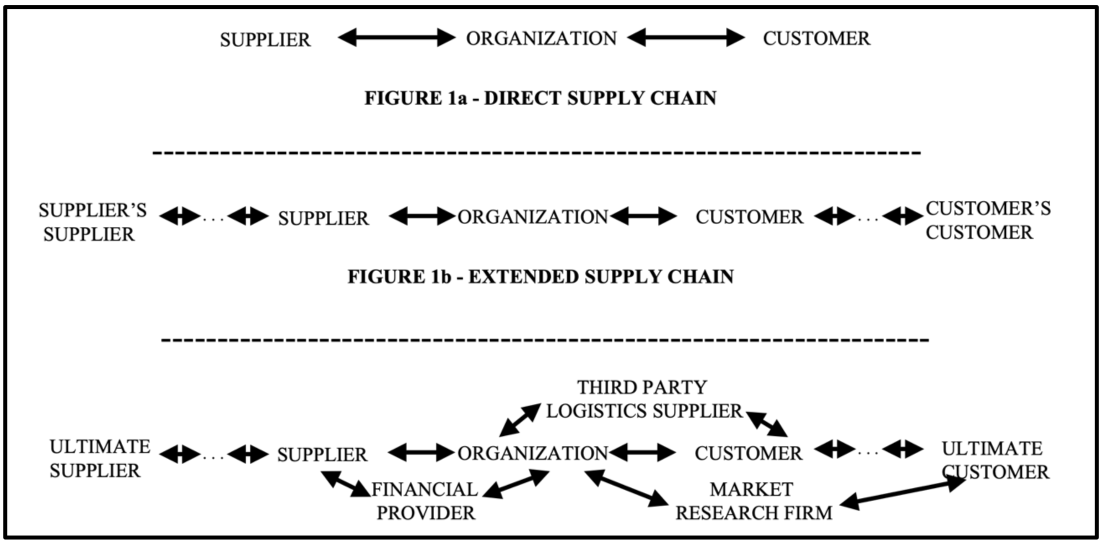


Figure 2.2: Three types of supply chain

Source: Mentzer *et al.* (2001)

2.2.1 Supply chain integration in Africa

Hospitals across African countries have experienced medicine stockouts for critical health conditions (Kuwawenaruwa *et al.*, 2020). Medicines need to be available and inexpensive to successfully prevent and manage endemic infections such as malaria (Lussiana, 2015; Lee *et al.*, 2017). Although some studies have evaluated the cost of medicine SC and affordability (Ferrario *et al.*, 2016), there is an urgent need for research on increasing patient access by examining the local factors that determine prices (Russo and McPake, 2009). Supply chains can come together to explore strategies that will lead to benefits from economies of scale, such as pooled procurement, which has been evaluated in SCs to improve cost efficiency (Kim and Skordis-Worrall, 2017; Ansbro *et al.*, 2020). Fu *et al.* (2017) examined different strategies to improve financial management, hospital SC governance, and staff incentives to reduce medicine costs and improve patient access. Orubu *et al.* (2019) discovered that some cardiovascular EMs were expensive and unaffordable to patients leading to decreased access. Geng *et al.* (2017) reported the differences observed in resource allocation and utilisation at service delivery points to improve service performance. Studies on SC service integration for human immunodeficiency virus and chronic non-communicable diseases have been conducted to improve patients' service delivery (Watt *et al.*, 2017). Donor-supported programs have weak integration with government-driven programs, such as the Global Fund-supported vertical HIV and TB programs with the national health system in the Lao People's Democratic Republic (Mounier-Jack *et al.*, 2010). Bruque-Cámara *et al.* (2016) demonstrated the benefits of SCI in improving supply chain performance by examining the effect of cloud computing on information and product flows. Performance can be enhanced by strategic partnerships between firms to share information, which improves operational efficiency (Zhao *et al.*, 2015). Most studies concentrate on private-sector SCs, and research on the complex public health sector in low- and middle-income countries is lacking. These countries struggle to fulfil the healthcare needs of their citizens and dwindling resources from donor agencies (Federal Ministry of Health, 2020). Hence, it is imperative to explore all means of increasing availability of medicines and reduce wastages from expiries. Strengthening regulatory frameworks and aligning governance structures has been linked to improved medicine availability (Miller and Goodman, 2016). However, ensuring systemic capacity must be available to institutionalise health sector reforms (Potter and Brough, 2004).

Nigeria's population of 200 million is projected to double by 2050, increasing the need to expand access to healthcare services for the burgeoning population. Healthcare coverage is below average and poor compared with smaller West African countries. Although the majority of Nigerians rely on public health facilities for the treatment of diseases, access to care has been poor over the years. Healthcare outcomes are not achieved, even with the concerted efforts of the government, donors, and stakeholders. One of the key factors in increasing access to health services is efficient supply chain and financial management (Lancet, 2022). Healthcare programs are financed by the government, donors, out-of-pocket expenditures, and other stakeholders (Uzochukwu *et al*., 2015). High out-of-pocket expenditures, limited insurance coverage, and insufficient government funding serve as barriers to accessing healthcare services. The current global recession and government dwindling resources coupled with donor fatigue make it imperative for Nigeria to fix the healthcare system which can lead to the achievement of UHC towards achieving the SDGs. The medicine supply chain system is fragmented, with frequent stockouts and expiries of essential medicines. The high importation of 95% of medical supplies as the local manufacturing sector can only cover 5% of local needs. Inadequate funding for essential medicine programs and wastage in the system are sources of concern for healthcare stakeholders. A national SC integration program was instituted to strengthen and integrate parallel program SCs (Federal Ministry of Health, 2018). The poor availability of essential medicines in the healthcare sector necessitates the need for interventions that can improve availability and reduce waste.

2.2.2 Kaduna public healthcare sector

The public healthcare situation at the federal level is reflected in all the thirty-six states. The Kaduna State healthcare sector is burdened by a lack of quality services and medicine stockouts. Although the state has tripled healthcare funding by 2019, there is a need to ensure the full coverage of citizens to achieve UHC (Kaduna State Government, 2021). Fragmentation in the SC coordination of the nine programs leads to the duplication of efforts between donor-funded SCs. Kaduna state has eight donor-funded program SCs and one government-funded essential medicine SCs, making a total of nine SCs. A diagnostic study conducted in 2016 found 6% essential medicine availability in 261 healthcare facilities. Medicine procurement is duplicated within and across programmes, leading to overstock and expiries. Lack of standardised processes, poor information sharing, inadequate SC capacity, and absence of coordination were reported in a diagnosis conducted in state primary healthcare centres. The report also indicated only 6% availability of lifesaving medicines in 251 surveyed hospitals (Health Strategy and

Delivery Foundation, 2015). Although the state government has engaged Zipline as a third-party logistics service provider, medicine stockouts persist in hospitals. The state has a procurement framework contract with local manufacturers and intends to begin manufacturing essential medicines in the future to ensure an adequate supply to hospitals. The state is focused on integrated public health SCs with streamlined information integration to foster coordination and reduce fragmentation and waste (Kaduna State Ministry of Health, 2021). To achieve the goals of the state, there is a need to examine the level of integration achieved thus far with supply chain partners by assessing internal and external integration with manufacturers and medicine suppliers. To reduce waste and high SC costs, financial integration and information integration between multi-echelon SC need to be investigated to identify enablers and barriers of integration that improve medicine availability. Successful integration of public health SCs requires monitoring of network performance in providing medicines to patients, which is measured using the essential medicine prescription fill rate.

2.3 Development of concept of supply chain integration

Hobday *et al.* (2005) defined systems integration as the capabilities that enable organisations to pool all inputs for future development. Systems integration evolved from systems engineering to becoming critical for strategic business pursuit that enables a firm to bring together subsystems, technology, knowledge, and people to create products that compete with other suppliers. The integration of supply chain systems involves many firms and actors, including government and regulatory agencies. The way buyers interact with each other (buyer-buyer relationship) is of strategic importance to the buying firms as well as the supplying firms (supplier-supplier relationship). Several studies have explored supplier-supplier relationships to improve performance (Wu and Choi, 2005; Wu *et al.*, 2010). These relationships can be dyadic involving buyer-supplier or triadic involving buyer-supplier-supplier relationships, which Choi and Wu (2009) argued to be the basis of building supply networks. Yadav *et al.* (2014) defined integration as "the merging of more than one vertical supply chain for specified programs or product categories". Although this definition considers the horizontal integration of vertical chains, it overlooks the essence of integration, which improves customer fulfilment. Li *et al.* (2009) viewed SCI as a focal firm's ability to combine activities within functional silos and between partners. Conversely, combining activities alone does not guarantee an improved performance, as noted by Danese and Bortolotti (2014). Chatzoudes and Chatzoglou (2015) advocate the implementation of a collection of strategies that lead to mutual benefits for internal and external partners through the movement of information and material resources. In addition, long-term relationships and bidirectional flows of both information and material improve competitive performance (Prajogo and Olhager, 2012). According to a study by Zhao *et al.* (2015), SCI refers to "the degree to which an organisation strategically collaborates with its supply chain partners and manages intra- and inter-organizational processes to achieve effective and efficient flows of products, services, information, money, and decisions, with the objective of providing maximum value to its customers". SCI involves the alignment and coordination of people, processes, information, and technology to enable an effective and efficient flow of resources to satisfy customer needs (Stevens and Johnson, 2016). Integration is the process of transmitting the real-time information necessary to make supply chain decisions (Al Dweiri and Isa, 2019).

2.3.1 Developing a conceptual framework for an integrated supply chain

The literature review from this study identified four levels of integration, from the internal processes of an organisation to external partner integration. External partners include suppliers, customers, and other network stakeholders. Financial flows and information sharing are critical for delivering products to customers, as identified in this study and shown in figure 2.3. Integrating processes, finance, and information within a network leads to improved network performance. Network performance is achieved when value creation benefits all partners in the SC.

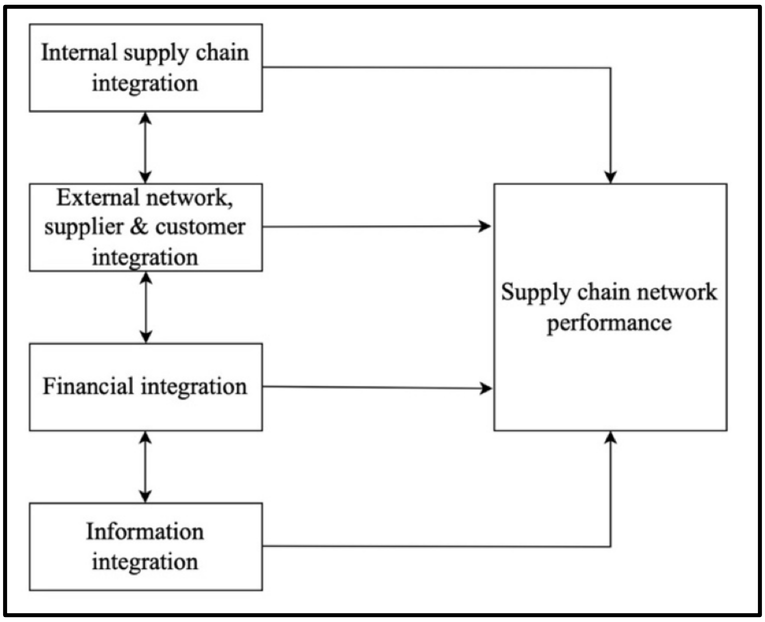


Figure 2.3: Conceptual framework for an integrated supply chain

2.3.2 Vertical and horizontal supply chain integration

While some studies advocate for vertical SCI due to peculiarities of product categories, thereby making a case for parallel implementation (Woodle, 2000), other studies believe there is some benefit in the horizontal integration of different product categories to supply chain processes, such as storage, transportation, and sharing of information systems (Yadav *et al.*, 2014). Conversely, the integration of selected activities proposed by Yadav *et al.* (2014), Maitra and Dominic (2016) can be counterproductive, as noted in Danese and Bortolotti's (2014) study which found that manufacturing plants that implemented multiple integration practices achieved higher operational performance in terms of quality, delivery, flexibility, and efficiency than plants that only implemented some selected SCI practices. Additionally, operational activities such as quantification, procurement, and requisition/ordering are difficult to integrate owing to the different demand planning, procurement, and order schedule processes of the SCs (Yadav *et al.*, 2014). Salam *et al.* (2019) reported that nutrition SC was operated using a separated channel and was one of the least integrated of the six (6) World Health Organisation (WHO) health systems building blocks. This was further highlighted in a study of five African countries, including Nigeria, with fragmented Sexual and Reproductive Health (SRH) and Human Immunodeficiency Virus (HIV) SCs. By contrast, Hope *et al.* (2014) argue that service delivery integration will not be effective unless the SCs of different programs are integrated. The study also explained that difficulties in integrating SCs arose from separate funding sources for SRH and (HIV) programs in five countries, including Nigeria. Mayhew *et al.* (2000) stated that while donor funding for HIV services is increasing and HIV SCs are fairly reliable, that of reproductive health is decreasing, leading to stockouts of contraceptives and other medicines for the treatment of sexually transmitted infections, making it difficult to integrate service delivery (Mayhew *et al.*, 2000; Hope *et al.*, 2014). Chi *et al.* (2013) proposed development of joint funding mechanism by different partners that handle the sourcing and management of SRH and HIV products. Bilateral donors have shifted toward jointly funding SRH and HIV SCs to achieve better service delivery. Integration of family planning and HIV care services has improved contraceptive use among HIV-positive female users (Baumgartner *et al.*, 2013). Hence, integrating procurement financing is critical to improving coordination and performance. Deploying a systems approach to funding different SCs helps determine feedback and behaviours driving medicine availability. Thus, there is a lack of consensus on the activities and extent of horizontal integration required to achieve the desired performance. Some studies see integration as a merger of SCs, whereas others emphasise the coordination of business processes to achieve customer satisfaction.

Bossert *et al.* (2007) proposed decentralisation for functions such as planning and budgeting, whereas inventory control and information systems remain centralised. Several studies have agreed on the need to integrate healthcare SCs for better performance (Table 2.1). The point of division is the level and extent of integration and the corresponding performance accrued to the integrated system. This research aims to determine the dynamic horizontal integration of essential medicine SCs to improve MAP. Hence, this study builds on the work of Yadav *et al.* (2014) and Zhao *et al.* (2015) to include network performance outcomes crucial to extending the definition of SCI in capturing customer centricity to improve the cost, flexibility, and reliability of the entire network in meeting customer needs. This customer-centric definition, as proposed in this study, links SCI to network performance. Meaningful integration considers the entire network of organisations, stakeholders, and customer benefits. If it only benefits suppliers, manufacturers, third-party logistics, and financial service providers without equally advancing the customer in terms of cost, flexibility, and reliability, then integration does not achieve network performance. Kotsi *et al.* (2014) suggested a harmonised supply chain as a solution to optimise medicine-donation SCs, and designing a framework for the integration of these fragmented health SCs is critical in guiding policymakers and supply chain managers. Integration approaches that work for a particular country may not work for another due to different contexts and extended timeframes of health reforms (De Savigny and Adam, 2009). Researchers have called for further country-level operational research on ISC and their service performances (Hope *et al.* 2014). Therefore, it is evident that SCs must align with service delivery performance. This study attempts to fill this gap by using a systems thinking and dynamics approach to explore SCI to reduce medicine stockouts and increase MFR. This study also develops a dynamic framework for SCI to guide organisations in achieving the desired outcomes from integration.

Table 2.1: Summary of supply chain integration concepts, strategies and levels of performance

No	Author (s)	Year	Concepts of integration	Strategies of integration	Level of performance	Outcome of study
1	Chang *et al.*	2013	Internal, external & information integration	Electronic procurement	Firm performance	Evaluated the effects of partner relationships and information sharing with integration in improving performance.
2	Zander *et al.*	2016		Supply chain governance	Network performance	Developed and tested a theoretical framework to determine the role of collaborative networks in improving operations. Identified process and IT integration to enhance communications across network partners.
3	Sangari *et al.*	2015		Knowledge sharing	SCOR processes of plan, source, make, and deliver	Developed a theoretical framework with six knowledge management processes that improve process performance.
4	Wakenshaw *et al.*	2017		Industry 4.0	Network performance	Discussed the benefits of CPFR and IoT in enhancing information sharing in the supply network.
5	Hataminezhad	2019	External & information integration	Product design	Product performance	Developed a model and Identified modularity in production and coordination as critical to improving product output.
6	Oh et al.	2020		Collaboration	Operational performance	Discussed the use of collaboration in contingency management to minimise losses and improve sustainability.
7	Madzimure *et al.*	2020		Electronic procurement	Firm performance	Assessed components electronic procurement and found design and negotiations in procurement processes.

8	Prajogo and Olhager	2012		Relational and IT competencies	Operational performance	Identified IT capability, information sharing and maintaining long-term partnerships to improve performance.
9	Nandi *et al.*	2020		Blockchain technology	Operational performance	Developed a blockchain integration framework to improve quality of products and reduce cost.
10	Shen and Chen	2020		Contract management	Quality management	Developed a framework and demonstrated the benefits of relationship management between partners
11	Menon	2012	Internal & external integration	Management and human resource practices	Inter-organisational network performance	Identified group trainings, workplace flexibility, and performance management as motivators for employee satisfaction with work output.
12	Seo *et al.*	2014		Innovation	Firm performance	Identified the positive influence of innovation, when used with supply chain best practices to increase performance.
13	Kang and Moon	2016		Collaboration	Relational and IT competence	Developed and tested a model showing that performance is achieved through collaboration of integrated SCs.
14	Ramirez *et al.*	2021		Trust and commitment	Operational and economic performance	Designed a model that established trust and commitment as enablers of integration of suppliers.
15	Sundram *et al.*	2016		Supply chain practices	Human resource performance	Evaluated a framework model and identified three variables that affect performance. The variables are quality of information, shared vison between partners and use of postponement during manufacturing.

16	Al Dweiri and Isa	2019		Knowledge sharing	Operational performance	Discussed the importance of sharing and using knowledge to improve partner relationship.
17	Uman and Sommanawat	2019		Supply chain flexibility and agility	Firm performance	Developed a conceptual framework for understanding and minimising risk in production.
18	Weeks *et al.*	2018		Flexible product manufacturing and routing	Financial performance	Discussed the implication of committing resources in manufacturing alone does not improve business profitability. Identified flexible production and routing proficiency as critical factors for success.
19	Kim *et al.*	2014		SCI strategies	Network performance	Developed a model that showed the importance of diversifying product coordination and cooperation among partners to increase market share and profitability.
20	Kumar *et al.*	2017		Supply chain design	Operational performance	Developed a conceptual framework to reduce costs and improve business profitability and ability to sense and respond to uncertainties.
21	Bagchi *et al.*	2005		Knowledge sharing and collaboration	Operational performance	Discussed the extent of integration as it affects operational cost and efficiency of SCs.
22	Maleki *et al.*	2012		Supply chain practices	Customer satisfaction	Proposed a model to increase customer satisfaction and reduce waste from overproduction.
23	Fatorachian and Kazemi	2021	Information integration	Analytic capabilities	Operational performance	Developed a framework that enhances information sharing and transparency and increases operational efficiencies in industries

24	Shafique *et al.*	2018	Internal & information integration	IoT capabilities	Green supply chain performance	Developed a model to analyse employee behaviour in reducing office energy consumption and increase speed of green practices adoption with IoT.
25	Abro *et al.*	2017		Enterprise Resource Planning (ERP)	Firm performance	Developed a framework to examine adoption of ERP systems. Identified technology, environment, and overcoming internal company constraints to effective ERP implementation rate.
26	Delic *et al.*	2019		Additive manufacturing	Firm performance	Advanced a theoretical model to improve performance with the adoption of additive manufacturing in industries.
27	Tiwari	2020		Industry 4.0	Firm performance	Developed a conceptual framework for integrating industry 4.0 in businesses.
28	Mofokeng and Chinomona	2019	External integration	Partnerships and collaboration	Knowledge and resource sharing	Developed a conceptual model and identified improvement in performance due to partnership and collaboration between ISC partners.
29	Yeh *et al.*	2020		Relational stability	Firm performance	Determined the effect of stable partnerships and uncertainty on performance
30	Piprani *et al.*	2020		Supply chain resilience	Operational performance	Examined a theoretical framework to assess the role of resilience and reducing uncertainties to improving customer service

Literature analysis indicates that there are multiple mediators and moderators of SCI and performance (Hassan and Abbasi, 2021). Although Ramirez *et al.* (2021) collected data from multi-tiered levels of the supply chain and identified trust and commitment as enablers of SCI, the study did not include other stakeholders' perspectives, such as suppliers and the government, making the story incomplete. In addition, Fatorachian and Kazemi (2021) used the systems theory with a focus on IoT integration. Fabbe-Costes and Jahre (2008) critically examined the literature and concluded that extensive integration does not lead to higher SCP, calling for more empirical research on SCI approaches. Prajogo and Olhager (2012) argue that long-term relationships are beneficial to businesses. Bagchi *et al.* (2005) found that the length of relationships with suppliers leads to higher SC costs and longer lead times. Additionally, multiple supply chain relationships between partners, such as hospitals and medicine suppliers, complicate the management of products and services for patients (Fawcett and Magnan, 2002). Thus, there is a lack of consensus among scholars on the right level of integration and relationship between SC partners, making a case for continuous empirical research to understand how SCI leads to performance.

2.3.2.1 Internal integration

Organisations use cross-functional teams to ensure product delivery to customers through the internal integration of processes and activities. An increase in internal integration improves the ability of companies to innovate product design, making it easy for employees to adopt new innovative practices (Ganotakis *et al.*, 2013; Seo *et al.*, 2014). Information systems and cross-functional integration, which enhance effective communication among partners, improve internal integration as teams can communicate effectively (Ganotakis *et al.*, 2013). Internal and external customer integration enhance SCP and financial performance, ultimately leading to customer satisfaction (Chatzoudes and Chatzoglou, 2015). Internal integration is argued to be a precondition for external integration to be successful when accompanied by flexible job descriptions, teamwork, and performance management, leading to SCP (Menon, 2012).

2.3.2.2 External supplier integration

External supplier integration and information integration are fostered by long-term relationships between firms and their suppliers (Prajogo and Olhager, 2012). External integration is the process of combining internal firm resources, processes, and capabilities with those of externally chosen suppliers to gain competitive advantage (Wagner, 2003). External supplier integration through electronic procurement, specifically electronic design and negotiation, positively influences SCI and improves supply chain performance (Madzimure *et al.*, 2020). Supplier integration leads to SCP by increasing speed, quality, and flexibility, while minimising cost (Chen *et al.*, 2013). Early Integration of suppliers into product development increases supplier knowledge and facilitates information sharing in complex technology which leads to improved outcomes (Petersen *et al.*, 2003). In addition to controlling the cost of the product and coordination to meet time schedules of product development, coordination instruments such as meeting proposals, patent analysis, project monitoring, and audits can be used from the concept stage to the product launch (Fliess and Becker, 2006). When there is uncertainty in the technology used for product development, either because it is new, complex, or rapidly changing, integrating suppliers can be beneficial in reducing the cost of the product by integrating the supplier's technology roadmaps into the product development cycle (Ragatz *et al.*, 2002; Chen *et al.*, 2013). Fulfilling promises on the part of the customer and refraining from opportunistic behaviour improves the relationship and access to suppliers' technology (Ellis *et al.*, 2012). Trust is important in customer-supplier relationships, but coercive power improves supplier integration in the absence of trust (Yeung *et al.*, 2009). Dependence on suppliers' technology increases the production of high product novelty, market share, and profitability (Yan and Azadegan, 2017). The risk associated with supplier integration includes spillover or leakage to suppliers who can use the knowledge to their advantage, become future competitors, or share information with current competitors. Flexibility in dealing with more than one supplier can mitigate the risks of technological and commercial uncertainties. Aligning strategies, technology and relationships is important for successful supplier integration and collaborative new product development (Perols *et al.*, 2013; Melander and Tell, 2014).

2.3.2.3 External customer integration

Customers are important co-creators in service delivery (Moeller, 2008). Integrating customers has benefits for the innovation process of a firm, as customers have information that is useful for the successful development of products. Relationships with customers increase customer loyalty to the brand and reduce errors during the design stage of products, leading to improved product performance (Urban and Von Hippel, 1988; Piller *et al.*, 2004; Zhang *et al.*, 2010; Maleki *et al.*, 2012; Hataminezhad, 2019). This contrasts Seo *et al.* (2014) study where customer integration was reported to have no effect on innovation. Although it is beneficial to integrate customers into the innovation process of an organisation, it also has a risk that could limit the innovation to incremental progress, serving only a niche market with a small group of people who share the same needs as the customer.

Customer integration can also lead to misunderstandings among company employees and dependence on customers' views and personalities. A company can lose its competitive advantage during co-creation with customers when its knowledge advantage is leaked to its competitors. Customers can also exploit this information to their advantage by displaying opportunistic behaviour (Enkel *et al.*, 2005). Chatzoudes and Chatzoglou (2015) found that working with customers has a significant benefit for SCP. Companies with customer integration competencies achieve better market success (Jacob, 2006). See summary of enablers of integration from previous studies in Table 2.2.

Table 2.2: A summary of internal and external integration enablers from previous studies on supply chain integration

Enablers of internal and external integration	**Author(s)**
Top management intervention	Kang and Moon (2016); Sundram *et al.* (2016); Shee *et al.* (2018)
Information sharing	Chang *et al.* (2013); Asamoah *et al.* (2016); Nandi *et al.* (2020)
Coordination and collaboration	Kim *et al.* (2014); Zhang *et al.* (2016); Hataminezhad (2019); Nandi *et al.* (2020)
Relational competencies	Prajogo and Olhager (2012); Chang *et al.* (2013); Jiang and Zhao (2014); Oh *et al.* (2020); Shen and Chen (2020); Yeh *et al.* (2020)
SC Governance and justice	Zander *et al.* (2016); Ziaullah *et al.* 2015)
Technology integration	Benton *et al.* (2016); Abro *et al.* (2017); Shee *et al.* (2018); Shafique *et al.* (2018)
Human resource practices	Menon, (2012); Tarifa-Fernandez *et al.* (2019)
Knowledge sharing	Sangari *et al.* (2015); Al Dweiri and Isa (2019); Ramirez *et al.* (2021)
Culture, trust, and commitment	Tsanos *et al.* (2014); Luo *et al.* (2018); Mofokeng and Chinomona (2019); Chen *et al.* (2013); Feriyanto *et al.* (2019)

2.3.2.4 Information integration

Information integration using various information technologies and systems is critical to SCI practices and enhances information sharing and knowledge exchange between suppliers and the focal firm, resulting in improved performance (Chen *et al.*, 2013; Asamoah *et al.*, 2016; Kumar *et al.*, 2017; Oh *et al.*, 2020). Strategic alliances and the adoption of a suitable information system are critical to achieving SC integration (Roy and Satpathy, 2019). According to Gonul Kochan *et al.* (2018), cloud-based information-sharing improves the visibility and ability of hospitals to align demand and supply, leading to a reduction in inventory costs and improved supply. Inter-organizational information communication and technology (ICT) systems improve SCI information sharing, collaboration, and the co-creation of values which increase SCP, even when demand is uncertain (Kocoglu *et al.*, 2011; Zander *et al.*, 2016; Zhang and Yang, 2016). Supply chain governance in the form of a collaborative network structure is essential for Information Technology (IT) integration and communication between organisations in the SC (Zander *et al.*, 2016). The six knowledge management processes enumerated by Sangari *et al.* (2015) include creation, capture, organisation, storage, dissemination, and application of knowledge, which have a profound impact on SCP. Knowledge management is significantly enhanced by IT integration irrespective of the supply chain strategy adopted (Sangari *et al.*, 2015). Electronic procurement enhances SCP through information-sharing, relationships, and SCI. Electronic sourcing has the highest impact on information sharing, while electronic negotiation impacts partner relationships and electronic evaluation affects SCI. Electronic sourcing and evaluation have a combined positive effect on SCP (Chang *et al.*, 2013; Pattanayak and Punyatoya, 2020). This contrasts with the findings from another study which showed that electronic design and negotiation had the most positive influence on SCI (Madzimure *et al.*, 2020). Table 2.3 below outlines some enablers of information integration.

Table 2.3: A summary of information integration enablers from previous studies on supply chain integration

Enablers of information integration	Author(s)
Electronic commerce	Chang *et al.* (2013); Madzimure *et al.* (2020); Pattanayak and Punyatoya (2020)
Blockchain	Nandi *et al.* (2020)
Internet of things	Wakenshaw *et al.* (2017); De Vass *et al.* (2018); Shafique *et al.* (2018)
Enterprise resource planning	Roh and Hong (2015); Benton *et al.* (2016); Abro *et al.* (2017); Nandi *et al.* (2020)
Supply chain visibility	Shen and Chen (2020); Cheung *et al.* (2012); De Vass *et al.* (2020)
Additive manufacturing	Delic *et al.* (2019)
Information system capabilities	De Vass *et al.* (2020)
Cloud systems	Shee *et al.* (2018); Salam (2021)
Industry 4.0	Dalenogare *et al.*, (2018); Salam (2021)

2.3.2.5 Financial flow integration

The flow of cash in SCs is hindered by financial impropriety and corruption in procurement practice. Owing to the unpredictable nature of disasters which necessitate emergency procurement in humanitarian logistics, situations that enable corruption in procurement can occur at different stages of planning, transportation, delivery, inventory management, and customer fulfilment. The use of procurement guidelines and standard operating procedures minimises corruption which is more common during emergencies (Schultz and Søreide, 2008). Inadequate financial controls increase the risk of leakage, particularly for consumer goods such as medicines and supplies. Organisations that manage their finances digitally experience an increase in cash flows accompanied by a decreasing risk of cash handling and mismanagement while improving visibility (Rodríguez-Espíndola *et al.*, 2020). In contrast to humanitarian SCs, where financial flows are downstream, DRF supply chain cash flow is upstream from the customer to the supplier. It is imperative to achieve transparency and accountability in public health care SCs. Sacristan-Diaz *et al.* (2018) proposed a sequential framework to flow within SCs, from internal to external, followed by information and financial flows, before product delivery.

2.3.3 Integration in healthcare supply chains

Healthcare supply chains use medicines, equipment, and health supplies from manufacturers and suppliers to treat diseases and conditions in patients and end users of hospitals and clinics. The goal is to alleviate disease conditions and improve patients' quality of life. Integration considers the alignment of patient's need to the supply of care by the hospital. The SCI approach in healthcare involves the coordination of people, products, processes, and technology to serve patients and increase their performance. Like industrial SCs, the healthcare sector has three flows: information, patients, and products. The coordination of these flows is critical for achieving desired clinical outcomes (De Vries and Huijsman, 2011). The complex nature of healthcare SCs and the involvement of multiple stakeholders present a unique opportunity to implement integration practices to improve performance. De Vries and Huijsman (2011) restated the prospects of knowledge transfer from industry SCs towards the implementation of the SCI approach for the benefits of end-users in healthcare settings. The publication of the Efficient Healthcare Consumer Response report in 1996 in the United States focused on medical and surgical supplies and pharmaceutical products (Consulting, 1996), and the implementation of information integration from the report led to performance improvements in healthcare supply chain management (Nachtmann and Pohl, 2009). Srivastava and Singh (2020) reported the positive impact of employee relationship, supply chain flexibility, organizational orientation, and knowledge exchange on performance of hospital SCs. This study demonstrated that improved ISC performance leads to better quality patient care (Srivastava and Singh, 2020).

Rivard-Royer *et al.* (2002) investigated a hybrid stockless system in the form of an integrated SCM system for Canadian hospitals. The case study focused on resource optimisation of the replenishment process by integrating external distributors and internal healthcare institutions, leading to marginal benefits for both using the hybrid method. Integration with the manufacturer led to substantial savings owing to improvements in the packing format and storage areas of products, demonstrating the importance of manufacturers in the integration process (Rivard-Royer *et al.*, 2002). They argued that the method should be renamed point-of-use or point-of-care distribution, as it better describes direct delivery to patient care units and eliminates central stores. This integration system also leads to financial benefits from savings and performance improvements in human resources. This study pointed out that very few SCI studies have empirically extended to patient care and called for the inclusion of point-of-use locations through information integration (Rivard-Royer *et al.*, 2002). In contrast, Gamme and Berg (2016) examined the enablers and barriers to operational integration in a hospital and an automobile industry mass producer, where common enablers include routines, standards, job rotation, and the use of verbal acknowledgement as rewards. The barriers to integration in the case study were culture, location, tacit knowledge strategies, and tasks (Gamme and Berg, 2016). Yadav *et al.* (2014) studied integration at functional levels of quantification, positing that it was challenging to integrate demand planning of vaccines with other health products because of the method of projection used to calculate the number of vaccines which differ from other medicines. Procurement was also a problematic function to integrate, as vaccines are procured through the United Nations Children's Fund, while other medicines are procured by the country's Ministry of Health or third-party contractors. The study also found that the cost of integration at the requisition/ordering point likely outweighs the benefits, as a routine order process is used for vaccines, whereas other medicines are requested based on the needs of the Health Facility (HF). Integration opportunities were identified in the storage, transport, and information systems, as other medicines share the same cold storage conditions as vaccines and can be transported together. Integrated information systems can be used to coordinate fragmented agencies. The study highlighted the benefits that can be achieved by integrating some functions of SCs, including savings in costs such as storage security, administration, transport, vehicles, fuel, and personnel costs, but did not demonstrate how this translates to operational performance for the end user (Yadav *et al.*, 2014).

2.3.4 Barriers to supply chain integration

Barriers to SCI include the absence of digital tools to share information on operational activities. Partners need to build trust to enable resource pooling and sharing of benefits and risks. SC capacity enables integration and a lack of know-how prevents partners from implementing strategies and practices of mutual benefits. Demand uncertainty and incompatible organisational culture and systems can deter SCI. The high cost of integration prevents companies from adopting integration practices (Sammuel and Kashif, 2013). Kumar *et al.* (2017) also identified distrust among firms, incompatible vision between firms, supply chain risk, bureaucracy, operational costs, and company culture. Conversely, some studies have reported that technology and financial capability are less of a constraint on SCI (Benevento *et al*., 2023). This could be due to the differences in the geographical context of the case studies, as some studies were conducted in Europe and other countries in Africa. Benevento *et al*. (2023) stated that the barriers to integration in healthcare SCs include "lack of motivation, resistance to change, a noncost-effective mindset, and a lack of initiative from health authorities or dominant players in the ecosystem". Therefore, it is interesting to note that healthcare managers might be resistant to changing the way they have operated for years, which can be linked to the organisational culture of doing things the way we have always done it. The lack of cost efficiency perception could be a result of deficiencies in SC knowledge and an understanding of the dynamic effects of decision making. Table 2.4 details some of the barriers to supply chain integration.

Table 2.4: A summary of barriers to supply chain integration from previous studies on supply chain integration

Author (s)	Year	Barriers of SCI
Sammuel and Kashif	2013	lack of ICT and information sharing. Mistrust and demand uncertainty, incompatible systems, SC knowledge gap, and high cost of SCI
Kumar *et al.*	2017	distrust among firms, incompatible vision between firms, supply chain risk, bureaucracy, operation costs and unfavourable company culture
Luo *et al.*	2018	SCM knowledge education and supply chain culture, lack of stakeholder buy-in, inadequate HR expertise
Gamme and Berg	2016	Culture, location, tacit knowledge, strategies and tasks
Panahifar *et al.*	2015	Incompatible partnership, lack of trust and cultural divergences between organisations

2.4 Supply chain performance

Avelar-Sosa *et al.* (2019) described Supply Chain Performance (SCP) as the capacity to decipher customer service expectation and the skill to meet the needs with the right product at the appropriate time as expected by the customer. According to Hausman (2004) SCP is "the extended supply chain's activities in meeting end-customer requirements, including product availability, on-time delivery, and all the necessary inventory and capacity in the supply chain to deliver that performance in a responsive manner". The SCP measures key indicators across functional and operational units within organisations which can also include the engagement of SC partners in cross-functional teams to adopt a shared measurement outlook. Performance measurements identified three key indicators for SCP efficiency in customer service, SC assets, and delivery velocity (Hausman, 2004). Companies must focus on multiple cross-functional performance indicators to ensure successful supply chain integration. Consequently, single-dimensional metrics can be misleading because the improvement in one level or process of the SC can push problems to another level. SCs create value for firms and customer stakeholders; hence, there is a need to measure SCP. It is important to measure multidimensional metrics across extended networks by using integrated performance measures (Figure 2.4).

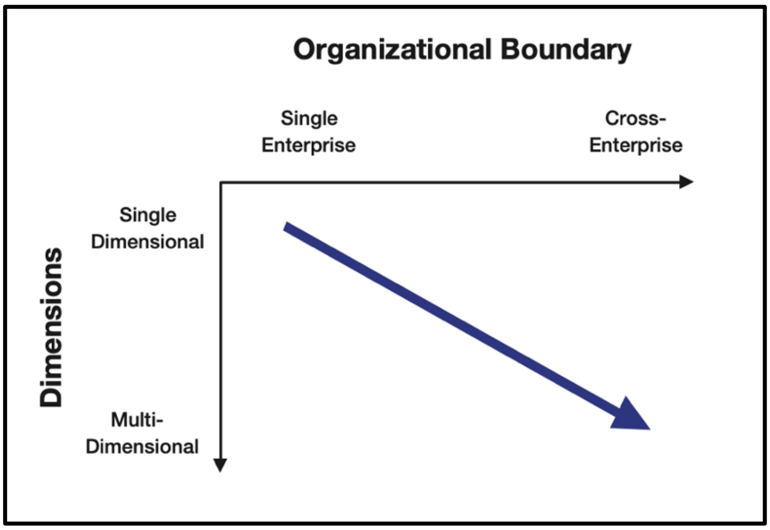


Figure 2.4: Evolution of performance measures for supply chains

Source: Hausman (2004)

Studies have identified different dimensions of performance achieved through the integration of SCs (Table 2.5), leading to improvements in finances (Zhang *et al.*, 2010; Nandi *et al.*, 2020), products (Zhang *et al.*, 2010; Maleki *et al.*, 2012; Hataminezhad, 2019), and process and operational performance (Maleki *et al.*, 2012; Prajogo and Olhager, 2012; Jiang and Zhao, 2014; Fekpe and Bray, 2015; Nandi *et al.*, 2020; Ramirez *et al.*, 2021). Green SC practices of minimizing waste and reverse logistics have been measured for their effect on cost, quality, and customer satisfaction leading to green SCP (Azevedo *et al.*, 2011; Shafique *et al.*, 2018). In contrast to the proposition of increasing resources for performance improvement, committing resources alone to improvement efforts does not increase financial performance of organisations (Weeks *et al.*, 2018). Thus, there’s a need to investigate the enabling factors for SCP.

Table 2.5: A Summary of supply chain performance typology from previous studies on supply chain integration

Types of Supply chain performance	**Author(s)**
Manufacturing flexibility	Weeks *et al.* (2018); Nandi *et al.* (2020); Dalenogare *et al.* (2018)
Green supply chain performance	Azevedo *et al.* (2011); Shafique *et al.* (2018)
Sustainable SCs	Radhakrishnan *et al.* (2011); Shee *et al.* (2018)
Network performance	Kim *et al.* (2014); Zander *et al.* (2016)
Firm performance	Kim *et al.* (2014); Zander *et al.* (2016); Abro *et al.* (2017); Dalenogare *et al.* (2018)
Financial performance	Zhang *et al.* (2010); Nandi *et al.* (2020)
Product performance	Zhang *et al.* (2010); Maleki *et al.* (2012); Dalenogare *et al.* (2018); Weeks *et al.* (2018); Hataminezhad (2019)
Process performance	Jiang and Zhao (2014); Weeks *et al.* (2018); Nandi *et al.* (2020)
Quality compliance	Nandi *et al.* (2020)
Operational performance	Maleki *et al.* (2012); Prajogo and Olhager (2012); Fekpe and Bray (2015); Yuen and Thai (2016); Dalenogare *et al.* (2018); Ramirez *et al.* (2021)
Innovation	Ganotakis *et al.* (2013); Seo *et al.* (2014); Corsini *et al.* (2018)
Supplier performance	Salam (2021)

2.4.1 Measuring supply chain performance

According to Parker (2000), companies measure performance to ascertain whether they meet customer needs and flourish. Identifying constraints and process flows in customer fulfilment is increasingly important while ensuring that set objectives are met using data driven decisions (Parker, 2000). Understanding the product and service needs of the end-user enables organisations to tailor marketing mix towards customer satisfaction. The four marketing mix of product, price, placement, and promotion must align with end-user needs of getting the right product at the right price, time, and location (Crandall *et al.*, 2015). Measuring performance allows companies to know whether the business is profitable and the level of profitability. SCP guides an organizations strategic direction in determining product development and customer offers by supporting management decision-making. Performance measures enhance communication and helps to give feedbacks to suppliers, staff, and stakeholders. Improving information flow also increases the flow of product and services. Performance Measurement (PM) encourages supply chain managers to monitor and sustain their ability to achieve organisational goals while guiding continuous improvement (Monczka *et al.*, 2015). One notable tool designed for PM is the balanced scorecard, which was developed by Kaplan and Norton in 1992 to link performance measures into four categories: internal, financial, customer, and innovation and learning. The scorecard addresses the challenges of traditional PM which focuses on financial performance by providing a holistic approach that considers the strategic goals of the organisation. The four domains of the balanced scorecard connect to strategic goals to drive customer-focused performance in improving product quality, reducing time to serve, and cost (Kaplan and Norton, 1992). Scorecards have been used in various industry settings, such as education (Karathanos and Karathanos, 2005), hospitality and tourism (Tahniyath and Saïd, 2020), and the banking industry (Frigo *et al.*, 2000). The growth and development of organisations varies when using the scorecard for PM which is reflected in the different levels of maturity for each company (Soderberg *et al.*, 2011). The balanced scorecard is widely used in healthcare (Inamdar *et al.*, 2002; Kocakülâh and Austill, 2007; Oliveira *et al.*, 2020) and humanitarian sectors (Anjomshoae *et al.*, 2017; Agarwal *et al.*, 2022), and researchers have called for modifications to the scorecard to align with the peculiarities of the industry (Zelman *et al.*, 2003). Some studies have stated the need for a systems approach to understand the factors that affect integrated PM in networks and organisations (Parker, 2000; Bititci *et al.*, 2012). Apart from knowing what to measure in businesses, it is also important to identify the level at which PM happens in an organisation depending on strategic, tactical, and operational activities (Gunasekaran and Kobu, 2007).

The Supply Chain Operations Reference model (SCOR) model deals with the processes of plan, source, make, deliver, and return of products and services to enable strategic decision-making in SCM. Developed by the Supply Chain Council (Stewart, 1997), the SCOR model seamlessly supports managers in operating SCs with network partners. To address the scarcity of strategic decision-making models, the SCOR model provides a decision-making tool across functions to improve process performance (Huan *et al.*, 2004). Combining the balanced scorecard and SCOR models has led to the integration of frameworks for PM and decision making (Chorfi *et al.*, 2018). In contrast, the SCOR model requires improvement to support organisational change and streamline operations management (Huan *et al.*, 2004). Another widely used tool is the maturity model assessment, which was developed and used to measure and improve the performance of companies. The Capability Maturity Model was the first model developed by Paulk *et al.* (1993) for measuring the growth of information technology advancement in organisations. Working with diverse stakeholders has led to the development of the first model to improve software processes and performance (Paulk *et al.*, 1993). The maturity model is a progressive representation of the performance outlook of a process or organisation as it approaches the benchmark or desired state (Wendler, 2012). Similar to the balanced scorecard, maturity assessment models provide different satisfactory analyses depending on the context and level of maturity sought by the company using the model (Estampe *et al.*, 2013). Maturity assessment studies have reported the ability to facilitate learning in organisations that use them for PM (Bititci *et al.*, 2015), with varying degrees of success indicated across industries such as construction (Willis and Rankin, 2012), asset management (Chemweno *et al.*, 2015), and supply chain management (Lahti *et al.*, 2009). In contrast to the observed successes, there exists the possibility of confusion on the part of staff regarding who and what to measure. More importantly, key performance measures must align with a company's strategy (Gunasekaran and Kobu, 2007). Collaboration is fundamental to organisational process integration, as stated in a study using maturity assessment to chart an increasing integration pathway (Aryee *et al.*, 2008).

2.5 Supply chain integration and performance

Behavioural antecedents, such as relational competencies, improve the stability of relationships which foster commitment and trust, leading to improved SCP. Relational stability mediates the relationship between SCI and SCP (Prajogo and Olhager, 2012; Chang *et al.*, 2013; Jiang and Zhao, 2014; Oh *et al.*, 2020; Shen and Chen, 2020; Yeh *et al.*, 2020). Organisations that have been engaging with their suppliers over a period of time and have built lasting relationships have benefited from performance improvements through information integration (Prajogo and Olhager, 2012). SCI mediates the relationship between SCP and supply chain management practices, such as the quality of information, postponement strategies, shared vision, and goals (Sundram *et al.*, 2016). Some studies have found a positive relationship between SCI and organizational human resource practices of increasing absorptive capacity (Menon, 2012; Tarifa-Fernandez *et al.*, 2019), top management intervention (Kang and Moon, 2016), and knowledge sharing (Sangari *et al.*, 2015; Al Dweiri and Isa, 2019; Ramirez *et al.*, 2020), leading to improved SCP. In contrast, other studies have reported that information sharing alone does not improve performance

(Baihaqi and Sohal, 2013) in the absence of organizational practices, such as coordination, which has a positive effect on product performance (Hataminezhad, 2019). Coordination is also enhanced by Industry 4.0, such as blockchain which improves coordination and leads to improvement in quality, process, flexibility, and reduction in cost and process time, conferring overall performance to the system. Blockchain technology systems have less effect on integration and collaboration at the SC strategic level (Nandi *et al.*, 2020). Enterprise Resource Planning (ERP) systems improve information sharing and coordination of operations, leading to SCP improvement in processes, flexibility, and quality compliance while reducing cost and process time (Roh and Hong, 2015; Benton *et al.*, 2016; Abro *et al.*, 2017). Conversely, this study attempts to understand the effects of information-sharing at the strategic, tactical, and operational levels of SCs. Information integration is required to develop supply chain relationships through trust, mutuality, reciprocity, and commitment. Although information integration impacts the coordination of operational activities, it has less effect on the actual production process which has a greater influence on performance (Tsanos and Zografos, 2016; Shee *et al.*, 2018). The adoption of an information sharing strategy leads to benefits in product design, modularity, and innovativeness (Ganotakis *et al.*, 2013; Seo *et al.*, 2014; Hataminezhad, 2019). The use of the Internet of Things (IoT) enables internal, supplier, and customer process integration, which leads to SC practices such as Collaborative Planning, Forecasting and Replenishment (CPFR) and SCP (Wakenshaw *et al.*, 2017; De Vass *et al.*, 2018; Shafique *et al.*, 2018). Therefore, evidence shows that information-sharing supports SCM practices of collaboration and coordination to improve performance.

Som *et al.* (2019), investigated the effect of information, operational and relational integration of SCs. The study concluded that information and operational integration had a positive effect on supply chain performance, whereas relational integration had a negative effect on performance due to issues of trust and long-term commitment (Som *et al.*, 2019). In contrast, Prajogo and Olhager's (2012) study found that long-term relationships facilitate external integration and performance, a position that was also echoed by Yuen and Thai's (2016) study, which found that close relations between partners led to better performance. Hence, there is a lack of consensus among scholars on the effects of relationships on performance, prompting the need for more empirical studies on the relational aspects of integration. Kotsi *et al.* (2014) identified four factors that prevent performance in medicine donations which are inability of programs to accurately forecast demand for products, lack of product visibility, inadequate distribution funding, and unclear communication protocols.

The study proposed that partners in health SCs can solve these problems by mapping SCs, managing existing partnerships, and end-to-end flows using real-time data collection, which can be used to model and optimise medicine-donation SCs (Kotsi *et al.*, 2014). However, it remains unclear what the structure of a harmonised supply chain looks like, and predicting feedback from improved communication channels among partners is unknown.

2.5.1 Supply chain integration and performance in healthcare sector

SCI and SCP in the healthcare sector have been examined by researchers seeking to identify means of improving healthcare delivery efficiency and reducing costs (Lega *et al*., 2013). Studies have examined the effect of integration on reducing delivery lead times by increasing network coordination, thereby shortening SC processes (Alzoubi et al., 2022). External manufacturer integration leads to cost savings as hospitals can obtain customised packaging and ship small batches more frequently, eliminating the need to stock large volume inventory that can lead to expiries and waste (Rivard-Royer *et al.*, 2002). The point-of-care method proposed by Rivard-Royer *et al.* (2002) reduces the storage space and medicine handling costs. The method also increases the potential for external customer integration through information sharing. Although adequate funding and the adoption of digital technologies for information sharing have been cited as barriers to SCI and performance, Benevento *et al*. (2023) found that hospitals with adequate funding and technology integration still face challenges with SCI. In contrast to the finding that healthcare organisations have sufficient funding for SCI programs and technology integration, healthcare SCs in Africa struggle with funding and digital technology infrastructure (Jahre *et al*., 2012; Yadav, 2015). Mbugua and Namada (2019) proposed network integration for hospitals with suppliers and patients to gain the full benefits of operational performance. Provision of reliable patient records and sharing of information with the network improves decision making and disease outcomes. The study also reported that hospitals should view patients as potential marketers for their services. Assessing the effect of integration on health organisations showed a direct positive relationship between internal and external integration on operational outcomes (Afrifa *et al*., 2021). Nartey *et al*. (2020) point out that SCI reduces SC costs and product quality by improving relationships with suppliers through risk and reward sharing. Several studies have highlighted the improved performance of healthcare SCs from SCI, but to date, no studies have examined the dynamics of integrating public healthcare SCs on essential medicine availability and improving patients' medicine fill rates. It is crucial to understand how improved performance in SC nodes increases medicine fill rate performance. Determining medicine availability through fill rates, as proposed by the WHO (2008), serves as a pointer on the effectiveness of SC governance to achieve patient-centric outcomes (Savedoff, 2011). Shifting the focus from hospital chains to patient outcomes paves the way for achieving UHC.

2.6 Supply chain relationship

Several studies investigated the relationship between integration and supply chain performance. Some studies have found a positive relationship between partnership, collaboration, and SCI in improving SCP (Kocoglu *et al.*, 2011; Radhakrishnan *et al.*, 2011; Ganotakis *et al.*, 2013; Tsanos *et al.*, 2014; Zander *et al.*, 2016; Zhang *et al.*, 2016; Mahadevan, 2017; Mofokeng and Chinomona, 2019; Oh *et al.*, 2020). Although Kang and Moon (2016) found a positive relationship between partner collaboration and SCP, the study reported that SCI had no direct effect on SCP but could indirectly improve performance through the collaboration of partners. SCs are moving towards network collaboration, as demonstrated by Poirier and Walker (2005) in figure 2.5, which leads to cohesion between parties (Mofokeng and Chinomona, 2019), as enumerated in the study of antecedents to collaboration, including trust, commitment, mutuality, and reciprocity (Tsanos *et al.*, 2014; Feriyanto *et al.*, 2019). This is in contrast to the finding that the lack of collaborative practices of information sharing, joint decision-making, risk, and reward sharing did not prevent SCP in the presence of internal and external integration (Shaikh *et al.*, 2020). Trust improves the relationship between hospitals and suppliers and leads to SCP (Abdallah *et al.*, 2017). Thus, from the literature, it appears that researchers have conflicting views on the relational competencies responsible for performance in integrated networks.

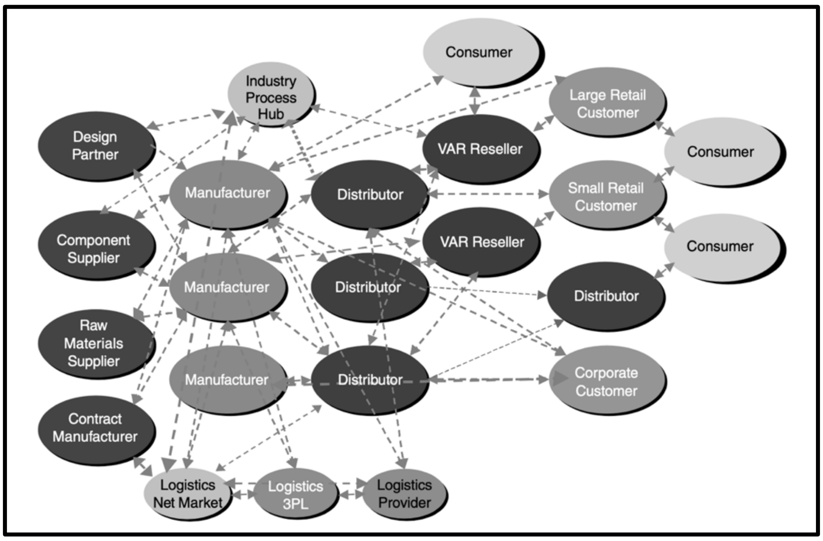


Figure 2.5: Supply chains are becoming collaborative networks

Source: Poirier and Walker (2005)

2.7 Theories in supply chain management

SCM has been studied using theories from various fields. Halldorsson *et al.* (2007) studied inter-organizational phenomena using economic, socio-economic, and strategic perspectives to develop a theoretical framework to explore third-party logistics and new product development. Researchers cannot rely on one theory to explain the SCM phenomenon; rather, several theories can be used to complement theoretical views to gain more insight into SCM (Halldorsson *et al.*, 2007). When organisations combine their resources, they improve their value and highlight the importance of inter-organizational ties. The improved resources create, shape, and drive the supply chain through personal chemistry between the partners, mutual trust, collaboration, and the use of systems for the benefit of both parties through the social exchange process. Network links are not fixed and continue to evolve to achieve short-term gains and position the organisation strategically for success (Johanson and Mattsson, 1987).

2.7.1 Resource-based view

According to Barney (1991), the resource-based view as a management strategy considers the valuable, rare, and costly to imitate the resources and capabilities of an organisation as economic rents and drivers of competitive advantage and organizational performance (Barney, 1991). Wernerfelt (1984) further classified resources as physical, human, and organizational resources that enable an organisation to develop, implement, and sustain strategies that improve efficiency and effectiveness, leading to a competitive advantage (Wernerfelt, 1984). Firm resources are heterogeneous and firm-specific. Therefore, they cannot be easily transferred or imitated. The resource-based view focuses on the competitive advantage conferred by firms' internal resources as opposed to the competitive environment in which the firm operates (Barney, 1991). Studies have demonstrated that the SCI of firms from inward to outwards facing leads to higher levels of operational performance (Schoenherr and Swink, 2012).

2.7.2 Transaction cost economics

In contrast to the resource-based view which focuses on maximising the value of a firm through the internal integration of resources, Transaction Cost Economics (TCE) focuses on minimising cost. Williamson (1985) defines transactions as the transfer of goods and services across entities without friction. The transaction cost is minimised in TCE and has been described by Williamson (1994) as an interdisciplinary undertaking between law, economics, and organisation. Williamson (1994) further postulated that law and the judiciary are reflected in the constraints of the organizational environment. TCE is a microanalytic study of economic organisations conscious of behavioural assumptions and asset specificity and uses institutional comparative analysis to determine organizational efficiency. It regards the business firm as a governance structure with emphasis on the outcome of investments (Williamson, 1985). TCE is mainly concerned with making or buying decisions in an organisation by determining whether to make the product internally or buy it from outside, depending on the decision-making entity in the firm or across firms (Williamson, 1975). Macher and Richman (2008) postulate that governance is critical in transaction cost economics, and firms are always compared with other firms to study the syndromes of each mode of governance. Simple transactions require a simple mode of governance, whereas complex modes of organisations are reserved for complex transactions to minimise costs. According to Whinston (2001), the concept of TCE assumes that market transactions have incomplete contracts and lock-ins, which makes the value of relationships higher than that of trading partners. This incompleteness leads to opportunistic behaviours by partners trying to increase their share of rents. TCE predicts the likelihood of integration as contractual incompleteness increases in market transactions (Whinston, 2001).

2.7.3 Network theory

Network Theory (NT) focuses on the interactions between different organisations in a network and the influence of partners on the relationship (Halldorsson *et al.*, 2007). NT emphasises the use of strong and weak ties to build supply chain reliability and flexibility and is useful in network knowledge management (Miles and Snow, 2007). NT promotes collaboration to foster trust, power, and economic gains (Uzzi, 1997), and provides a better understanding of the inter-organizational relationship processes between partners in the supply chain. The three (3) constructs of NT are activities, resources, and actors (ARA), which are used to explain business networks and inter-organizational relationships (Gadde *et al.*, 2010). SCM inter-organizational features, such as process integration, vendor-managed inventory, and CPFR, serve as operational frameworks at the inter-organizational supply chain level (Halldorsson *et al.*, 2007). Studying whole networks can improve the understanding of service delivery in the public health sector (Provan and Milward, 1995) and inter-organizational competitiveness (Human and Provan, 2000). Provan *et al.* (2007) called for the inclusion of organisations in network-level research to study their engagement and readiness for networking.

2.7.4 Systems engineering theory and system dynamics

A system is a group of people, processes, technologies, and facilities that are defined by stakeholders to achieve a common goal and characterised by subsystems. System engineers work with stakeholders to identify their goals and build a system to achieve them (Buede and Miller, 2016). Systems engineering dates to early 1900 from the work of Bell Telephone Laboratories during World War II (Fagen, 1978). Systems engineering has evolved owing to increasing complexity and interactions between organisations and the expanding environment in which the system operates. The environment, such as the economy, technology, and other subsystems, is external to the system and creates tensions within the system. The rising use of technology to meet societal demands also creates the need to design systems which can satisfy this demand (Hall, 1962). The more difficult the problem, the larger the resources needed to solve the problem. System Engineering is used to mitigate the uncertainties encountered in solving complex problems. The lack of technical competence in solving problems has also increased the need for systems engineering, where organisations optimise the use of scarce resources to improve efficiency. Hall (1962) concluded that the best way to define system engineering is through the processes of conducting system engineering which involves program planning, project planning (I and II), and the action phase (I and II). Systems engineering considers physical, logical, and social aspects to align a system's function with the environment (Watson *et al*., 2019). The general systems engineering theory identifies the connections between different systems (Bertalanffy, 1968). The system dynamic approach to systems theory was proposed by Forrester (1968), who introduced the structure and behavioural modelling of social systems for a better understanding of decision-making in complex systems. Forrester highlighted the importance of feedback systems otherwise known as closed systems where the output from the system affects it's behaviour. Unlike open systems, the system behaviour is not affected by the output. The feedback systems are characterised by negative goal-seeking and positive growth closed loops. The structure of the problem is critical for examining the behaviour of the system. The concept of a structure contains a closed loop with a boundary. Feedback loops contain levels and rates which are policies that can change the system. The rates consist of the current condition and goal of the system, the difference between the goal and current states, and the action from the difference. The depiction of the system as a simulation model allows researchers to observe behaviour over time (Forrester, 1968).

2.7.5 System dynamics theory

The publication of industrial dynamics by Forrester in 1958 paved the way for an understanding of dynamic systems theory in supply chain management based on feedback control theory. Management policies in SCs lead to feedback that alters the system, necessitating a change in the direction of upcoming decisions. Systems feedback control affects all aspects of human behaviour and organisational decision making in the production of goods and services. In global economics, as developing countries move towards industrialisation, they will have to answer some of the questions on economic development to build stable and prosperous societies, highlighting the need to develop the capacity and capability to build efficient SCs (Forrester, 1961). System dynamics (SD) uses the structure of the system of interest combined with time delays in information sharing and amplification to understand the behaviour driving the system (Forrester, 1961). Systems dynamics, as a structural and content theory, underpins and assists the unravelling of salient developmental problems in logistics and SCM. By experimenting with modelling and simulations, SD provides researchers with a means of testing or simulating the theory which is represented as a model when it is impractical to do so in real life. Systems feedback, delays, and accumulations characterise complex adaptive supply chain systems better explained by SD structural theories (Größler *et al.*, 2008). SCM is a critical agenda for top management intervention and continues to defy solutions with increasingly diffused oversight and elusive service level performance, leading to the call for an integrated approach (Sharman, 1984). Sharman reports that the cost of demand planning, forecasting, technology, procurement, and order fulfilment are overlooked by managers while inventory handling cost is underrated. Angerhofer and Angelides (2000) called for more research on inventory management and customer fulfilment in various practical fields. These challenges, among others, led to a proposed move away from vertical integration towards supply chain network integration, as no single organisation is responsible for its entire supply chain (Akkermans and Dellaert, 2005). Conversely, organisations still find it difficult to achieve the right balance of integration to achieve the best solution for the network and value creation for customers. This study attempts to fill this gap by proposing a system dynamics theory to underpin the network integration of SCs.

2.7.5.1 Supply chain management and Simulation

Simulation is still not widely used in healthcare problem solving compared to other sectors, such as military and manufacturing (Baldwin *et al.*, 2004; Pitt *et al.*, 2016). Bekker and Guittet-Remaud (2000) used the Arena model, Microsoft Access database, and Microsoft

Excel worksheets to simulate a model of SCI using the Supply Chain Operations Reference model (SCOR) to model four processes: plan, make, source, and deliver. Maina and Mwangangi (2020) reviewed four case studies in the petroleum, chemical, information technology, and automotive SC industries that used simulation models to improve decision making and performance. The study concluded that integrating optimisation models will deliver better options for decision makers and improve their performance. SCI modelling can be performed at the strategic, tactical, and operational levels (Stevens, 1989). It can also be carried out using partnerships, network structures, and processes that link supply chain partners (Cooper *et al.*, 1997). The complexity of SCs and the shortcomings of standalone mathematical models call for research into designing model-based decision support systems driven by IT systems. This study also classifies supply chain models into deterministic, stochastic, hybrid, and IT-driven categories (Min and Zhou, 2002).

2.7.5.2 System dynamics modelling and simulation

System dynamics (SD) have been used in the healthcare sector to prevent stockouts due to uncertain lead times and demands using safety stocks (Kumar and Kumar, 2015), disease screening and development of emergency care (Royston *et al.*, 1999), workforce planning (Ansah *et al.*, 2019), and to improve performance and service quality (Oliva and Sterman, 2001; Gönül-Sezer and Ocak, 2020). SD has contributed to the modelling of antiviral supply chain integration with epidemic outbreaks (Paul and Venkateswaran, 2017), SCP, and cost (Bam *et al.*, 2017). SD was used to expand the theory of capability traps to include nested and caseload dynamic traps in social sectors, including healthcare (Landry and Sterman, 2017). Darabi and Hosseinichimeh (2020) studied the use of system dynamics in healthcare delivery and showed that only a few studies focused on organizational management and performance improvement using system dynamics modelling. SCs are dynamic in nature, and a system dynamics modelling technique is used to model abstract systems without disrupting the environment of the real system. This has led to calls for simulations to understand SCs in different settings (Dey and Sinha, 2019). Other studies used discrete event simulation for inventory management optimisation (Al-Fandi *et al.*, 2019) and allocated resources in patient flow studies (Jun *et al.*, 1999). Evaluation of the equity impact of substandard and falsified antimalarials among children under five years of age was unravelled using agent-based modelling (Evans *et al.*, 2019). Unlike discrete event and agent modelling, SD provides the opportunity to explore the phenomena of interest, design, and test policies that impact the entire system. Thus, SD can help managers and policymakers anticipate changes in policy implementation and navigate resistance to change.

2.7.6 Developing a theoretical framework for an integrated supply chain

The theoretical framework of this study is underpinned by system dynamic theory which accounts for the network structure, delays in decision-making, and feedback from the effects of changes in the network environment (Angerhofer and Angelides, 2000). Addressing the gaps in the literature review helps achieve the aim of this study which is to determine the effects of SCI on the availability of medicine in public healthcare supply chains using four specific objectives to examine how levels of integration and viability of public health SCs improve medicine availability. This study also develops and validates a dynamic theory for integrating SCs. Supply chains have gone beyond the control of a single organisation and are more appropriately termed integrated chains or supply networks. This complexity requires a more holistic management approach, as no single entity controls a supply network (Akkermans and Dellaert, 2005). Akkermans and Dellaert (2005) highlighted the need to understand the dynamics of complex supply networks to achieve better performance and restate the importance of system dynamics in supply network studies. Holweg and Disney (2005) identified discrete time, continuous time, and the control theory approach as the three methodological approaches to study the dynamic behaviours of supply chains. First, discrete-time approaches presume that events occur in SCs at specific times (*Lee et al*., 1997). This can be a hospital that sends replenishment orders every week, even when patient prescriptions are received daily. Replenishment of medicines weekly occurs at discrete intervals, making discrete-time approaches suitable for events that occur at specific intervals. Second, the continuous-time approach allows the observation of the system rate of flow over time using differential equations which align with Simon's (1952) use of servomechanism theory and Laplace transform methods to study the behaviour of control systems in product manufacturing. Furthermore, Forrester's (1958) use of Dynamo to examine the dynamics in multi-tier SCs is the bedrock of system dynamics as a continuous-time model. Unlike discrete time models that allow observations at a specific time, continuous time models are suitable for observing whole systems where time delays change the differential equation into non-linear equations that create insights into dynamic system behaviours. Finally, the control theory approach is a derivative of discrete and continuous models but is limited in modelling SCs with more than two echelons (Holweg and Disney, 2005).

System dynamics modelling for supply chain management has its root in Forrester's (1958) work on industrial dynamics which considers the relations between the different flows in a system, such as products, information, people, and materials from the manufacturer to the customers. The essence of SD is to understand the system behaviours and design policies that can improve the performance of the system. SD has been used to explore strategic decisions, such as supply chain integration, capacity management (Georgiadis *et al.,* 2005), subsidy policy for green SCM (Tian *et al*., 2014), and SC flexibility (Singh *et al.,* 2019). SD methods have been used in the healthcare industry to improve performance by examining information sharing (Gonul Kochan *et al.*, 2018), the bullwhip effect (Samuel *et al*., 2010), SC disruptions (Sigala *et al*., 2022), and minimising waste and fake vaccines (Andiç-Mortan and Gonul Kochan, 2023).

The adoption of SD methods to examine SCI in this study is based on four considerations. First, the use of SD modelling to explore SCI allows for the observation of the public health SC system because it is impractical to do so in real life. Healthcare SCs are complex and involve multiple stakeholders working together to make medicines available to end-users. Public healthcare SCs stakeholders include but are not limited to medicine manufacturers, raw material suppliers, distributors, regulatory agencies, insurance companies, donors, implementation partners, country governments, logistics service providers, and community representatives. The composition of stakeholders may vary according to the goals of the SC programme. This unique configuration makes it impractical to study healthcare SCs in real life because there is no single entity responsible for the SC. Hence, the SD model is suitable for this study. Second, the SD model is suitable for exploring strategic decision making, as demonstrated by Georgiadis *et al.* (2005). SCI is a strategy used by SCs to improve coordination and collaboration with partners to improve the flow of products, people, information, and money through the multi-echelon SC and enhance decision making. The strategic focus of SD makes it ideal to evaluate SCI in this study. Third, SD models support the continuous observation of the dynamic behaviour of systems which is necessary to gain insights into the effects of integration on improving medicine availability. The end goal of the SD model is to improve performance which aligns with the aim of improving the medicine fill rate performance. Finally, SD, as a structural and content theory, provides a means of testing and simulating theories (Größler *et al.*, 2008). The use of SD methods in this study enables the testing, simulation, and validation of SCI theory. The structural and content theories from this study enrich dynamic SCI theory.

2.7.6.1 Theoretical framework concepts

The concepts of the SCI theoretical framework are derived from internal information, external suppliers and stakeholders, external customers, and financial integration, which lead to network performance (Figure 2.6). The double-edged arrows show dynamic behaviour where integration affects performance and vice versa. When supply network partners achieve their goals, they create an incentive for greater collaboration, which leads to a reinforced performance loop.

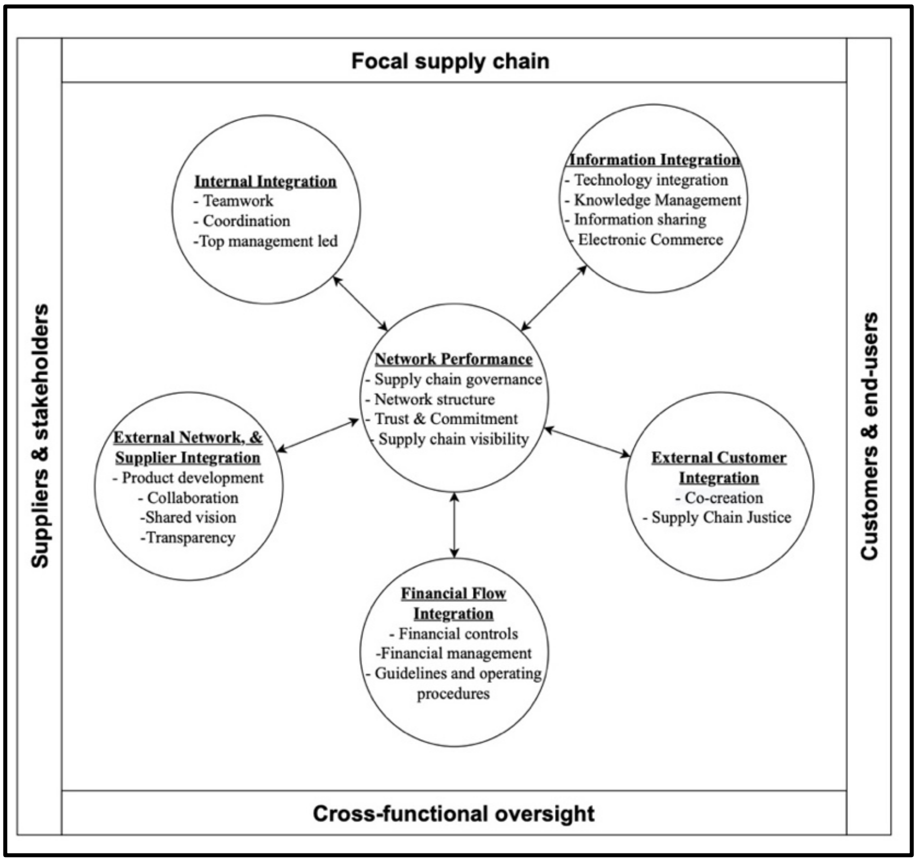


Figure 2.6: Theoretical framework of an integrated supply chain

First, internal integration is the ability of organisations within the supply network to work seamlessly with their team members. Customers, patients, and end users are the ultimate beneficiaries of the public healthcare system. Hence, determining the success of internal and external supplier and stakeholder integration is measured by customer satisfaction with the medicine provision. The structure of SC operations where products, money, and processes flow through the organisation necessitates the use of human resource practices that increase teamwork in the focal organisation (Menon, 2012; Tarifa-Fernandez *et al.*, 2019). Seamless interaction in product design and other processes of customer fulfilment is achieved through the coordination of SC activities (Hataminezhad, 2019: Nandi *et al.*, 2020). Supply chains that lack relational competencies struggle to develop SC relationships within and across organisational boundaries (Tsanos and Zografos, 2016), leading to decreased performance. Internal integration involves the end-to-end process integration of the order fulfiment, and the cohesion of SCs is a strategic decision and must be led by top management (Kang and Moon, 2016; Shee *et al.*, 2018). Second, information integration supports the sharing of critical information in a network to enable the movement of goods and services using technological systems (Shee *et al.*, 2018). Previous studies examined the use of ERP systems to improve performance (Benton *et al.*, 2016; Abro *et al.*, 2017). Information sharing is crucial when implementing SC interventions with high uncertainty to enhance communication between parties and resolve conflicts (Zhang *et al.,* 2016). IT integration also improves knowledge management and helps teams to share knowledge and practices. Knowledge diffusion across private and public institutions harmonises processes and procedures to ease the flow of products and services (Sangari *et al.*, 2015). Third, moving across organisational boundaries to integrate with suppliers and partners is a critical next step for SCs that have strong teamwork ethics. Reaching across inter-organisational boundaries is necessary because of the global nature of SCs, cutting across multiple organisations. Collaboration with suppliers improves product development. Working with multiple stakeholders is important for delivering the desired health outcomes to essential medicine chains. Relational capabilities and stability are necessary for external supplier and stakeholder integration to increase collaboration (Prajogo and Olhager, 2012; Chang *et al.,* 2013; Jiang and Zhao, 2014; Oh *et al.*, 2020; Shen and Chen, 2020; Yeh *et al.*, 2020). Having a shared vision with transparency makes collaboration easy, as different organisations within the healthcare sector pursue the vision of saving lives. Integrating the processes and activities that contribute to shared vision helps achieve network performance (Sundram *et al.*, 2016).

Fourth, external customer integration increases innovation in an SC as customer voice is reflected in product design, leading to increased market performance (Jacob, 2006). There is also the risk of becoming dependent on customers and losing the innovative edge (Enkel *et al.*, 2005). While some studies have reported a lack of innovativeness in customer integration (Seo *et al.*, 2014), it is imperative to work closely with customers in service SCs, such as healthcare. Ziaullah *et al.* (2015) argues that supply chain justice is necessary to curb the opportunistic behaviours that may arise from customer integration due to exploitation of bigger firms over weaker companies in the network. Fifth, financial performance is the goal of every SC, underscoring the importance of financial integration in supply networks as a crucial flow that needs to align with product flow. Implementing robust financial controls prevents leakage in healthcare SCs. Digitalisation of the cash collection process increases transparency in the system and builds trust (Rodríguez-Espíndola *et al.*, 2020). Prudent financial management involving the use of standard guidelines and procedures allows performance management and benchmarking. Finally, the outcome of SCI is improved network performance, in which all stakeholders benefit from the system. Network performance is anchored in supply chain governance which supports the network structure. Stakeholder trust, commitment, and supply chain visibility and transparency enhance network performance. Since no single entity controls a supply network, SC governance must be instituted to foster trust and commitment in the integrated system. Ghosh and Fedorowicz (2008) explain how the three constructs of governance–trust, bargaining power, and contracts–affect information sharing, leading to improved coordination and SCP. In addition to examining the construct of contracts, Dolci *et al*. (2017) evaluated relationships and transactions as governance constructs. The results showed that supply chain governance improves operational and financial performance by reducing costs and increasing returns on investment.

2.7.6.2 Measuring public health supply chain network performance

Network performance goes beyond individual organisations within the SC and looks at how the entire supply network can achieve the goal of providing medicines to customers. Supply chain governance has been proposed as a mechanism for orchestrating multi-stakeholder supply networks to achieve the desired goal of delivering value to customers using governance instruments, such as contracts, standard procedures, SC visibility, and trust (Pilbeam *et al*., 2012). Governance instruments are useful in building trust and commitment among partners. However, they do not identify specific network performance outcomes (Savedoff, 2011). To understand the outcomes of integration in healthcare SCs, essential medicine availability and stockout rates in hospitals are key performance indicators for measuring SC governance performance (WHO, 2008). Measuring the fill rate of essential medicines as an outcome of network performance shows the success of SCI and supports the aim of this study which is to determine the effects of SCI on the availability of medicine in public healthcare supply chains. Unlike industrial SCs, in which financial measures are the most critical metric, the healthcare sector measures success based on patient-centric outcomes (Savedoff, 2011). The order fill rate is also used in industrial SCs to measure customer service levels, particularly in build-to-stock models (Hausman, 2004). Financial improvement is not ruled out in public healthcare SCs, as studies have reported cost savings and the efficient management of medicines from SCI (Lega *et al*., 2013). This study used medicine fill rate performance as an SC governance performance metric to examine the levels of integration and viability of public health SCs to improve medicine availability. This study also develops and validates a dynamic theory for integrating SCs. Understanding the performance outcome of integration helps SCs develop integration strategies for efficient management of supply networks. This study enriches the dynamic theory of SCI, with an emphasis on improving MFR performance and empowering supply networks to have a patient-centric approach rather than focusing on their organisations or SC systems.

2.8 Identified gaps from literature review

A critical review of the literature revealed gaps in previous SCI studies. First, the level of integration required to achieve desired performance remains unclear. The connectedness between partner organisations that will ensure mutual gain is still a subject of research. Some studies have called for multiple integration (Danese and Bortolotti, 2014), while others have cautioned about the integration of SC processes (Yadav *et al.*, 2014; Maitra and Dominic, 2016). Second, researchers have suggested activities and processes to improve performance (Kocoglu *et al.*, 2011; Radhakrishnan *et al.*, 2011; Ganotakis *et al.*, 2013; Tsanos *et al.*, 2014; Zander *et al.*, 2016). However, there is no clear framework on the extent of benefits at the service level that can be achieved when businesses come together, and how partners can continue to navigate the integration process for continuous value creation. The literature review also showed that the reasons behind the lack of consensus on supply chain integration and performance is because organisations overlook the effect of dynamic feedback, delays, and system structure in the integration process, leading to different outcomes for businesses and customers. Thus, it is vital to study the dynamics of SCI and its performance to address gaps in previous studies. Third, although cash flow is vital for all businesses, some studies overlooked the effect of cash flow integration on performance (Abushaikha, 2014). This study considers the cash flow integration that is necessary to achieve network performance. Finally, SD studies on SCI did not consider shrinkage and expiries of medicines together with capacity limitations, as underscored by Paul and Venkateswaran (2017), calling for more research in medicine SCs. This study fills the gaps identified by developing a three-tiered integrated essential medicine SC with consideration of strategies and capacity constraints leading to improved MFR performance.

2.9 Conclusion

This chapter begins with a definition of the concepts of supply chain management, SCI, and SCP. The relevant literature on levels of integration was analysed and discussed to develop a conceptual model of SCI and performance output. The levels of integration and theories underpinning different studies were used to examine and understand previous approaches to analysing SCI. System dynamics theory was used to develop a theoretical framework for integration, leading to improved network performance and medicine availability. Identified gaps in the literature help address how to integrate SCs to obtain the desired MFR from a system dynamics perspective.

3 RESEARCH METHODOLOGY

3.1 Introduction

The philosophical perspective of this research on supply chain management as a social science field is derived from the sociological dimension of the nature of science and core assumptions of ontology, epistemology, and methodology. This section presents the research paradigm, approaches, and dynamic system methodology used to explore supply chain integration. Data collection methods and the rationale for mixed-method data collection and interpretation are outlined.

3.2 Research philosophy

Research philosophy deals with an approach to explore the nature and development of knowledge. This research philosophy is derived from the assumptions of ontology and epistemology. First, ontology is the study of the nature of reality (Saunders *et al*., 2009). Philosophers along the divides of natural sciences and social sciences have debated over decades about what people perceive as reality and expectations versus relativism. Ontology, as a study of reality, can be explained from two perspectives, realism and relativism. Natural science realist views the world as concrete and external to the researcher and can only be observed directly without interaction with the researcher. Transcendental realism, a less extreme assumption of realism believes that object of scientific research exists and act independent of the researcher and their activity (Bhaskar, 1989). Internal realism assumes the existence of a single reality, and it is impossible for the researcher to access this reality directly through a physical process (Putnam, 1987). This affects the phenomenon under experimentation, which is why internal realists believe that discovered scientific laws are absolute (Easterby-Smith *et al*., 2012). On the other hand, relativism assumes scientific laws exist out there and can be created by the researcher (Latour and Woolgar, 2013). Debates in the field of social sciences focus on internal realism, relativism, and nominalism, as they relate to human behaviour and whether assumptions and methods from natural sciences are applicable to research in the social sciences (Blaikie, 2007).

Second, epistemology deals with studying the nature of knowledge and ways of enquiring into physical and social worlds. The physical world can be viewed through the lens of objectivist and constructivist epistemology. Objectivism argues that the researcher is detached from the object of observation and does not interfere with giving meaning to the phenomenon of interest. Constructionism concerns the interaction between the researcher and the object of study to gain meaning. The researcher is an active participant and depends on the object of the study by constructing reality from internal experience. While strict adherents of objectivism and constructivism exist, others have argued that the full benefit of epistemology is realised when context is considered in the application of epistemological assumptions (Jonassen, 1991). Although philosophers have argued over different ontological and epistemological positions, one common theme is that both branches of philosophy are not static, and are always viewed as a continuum (Easterby-Smith *et al*., 2018). The ontological and epistemological assumptions of a researcher on reality and creating knowledge about the world lead to the generation of a set of principles guiding research, known as the research paradigm (Kuhn, 1962). These guiding principles help the researcher to select appropriate methodologies and methods to conduct research.

3.2.1 Axiology

Axiology is a philosophy that deals with the study of the nature of value, including our values, in the fields of ethics and aesthetics. The value of the researcher determines the outcome and credibility of the research. Values are important in determining the right ethical decisions and guide the researcher in exploring the phenomenon (Saunders *et al*., 2009). Depending on the research philosophy, axiology determines a researchers' perception of value and approach to engaging the phenomena. A positivist approach perceives the research as free from values and engages the phenomenon from an objective perspective without interaction. Social constructivism perceives research to be controlled by values and the researcher is subjective and inseparable from data collection. Constructivists engage in enquiry to understand and interpret reality which can be multiple. Hill (1984) argued that values determine the selection of research to conduct and can also lead to a decision on when to stop further investigation. Saunders *et al*. (2009) contended that every decision taken during a research process is informed by the values of the researcher. For example, conducting personal interviews shows that the researcher values interaction with the respondent using a constructivist approach, while a positivist might conduct a mail survey for the same research topic. The lack of contact with the respondent indicates that the researcher does not value the interaction with the respondent.

3.2.2 Research paradigm

The research paradigm was popularly coined from Kuhn's 1962 publication, where he argued that scientific researchers that practice under similar rules and standards have common understanding and paradigms, leading to fewer disputes on the essentials of research. Paradigms are a set of agreed research guiding principles that were initially associated with the natural sciences but have since been adopted in the social science context. The two main research paradigms guiding social science research are positivism and social constructionism as extreme positions. Other researchers have argued for intermediary positions along the continuum of these two extremes. Easterby-Smith *et al*. (2018) considers critical realism as a hybrid of positivism and constructionism with closer ties to positivist paradigm while Moon and Blackman (2014) argue that critical realism is an ontological position where reality is subjected to critical scrutiny. The positivist paradigm is mainly used in natural sciences, and views reality as objective and independent of the researcher. Conversely, social constructionism is mainly used in the social world, and views the world as a socially constructed reality (Saunders *et al*., 2009). The dichotomy of single versus multiple truths has dominated philosophical debate for centuries (Kuhn, 1962). The struggle for superiority of the positivist paradigm over the constructivist led to paradigm wars, which lasted over the decades until some researchers proposed the pragmatist approach to pacify the two extreme positions. Pragmatists believe that the use of both positivist quantitative methods and constructivist qualitative methods can coexist within the pragmatism paradigm. The pragmatist paradigm uses quantitative and qualitative methods in a mixed-methods research design (Tashakkori and Teddlie, 1998). Pragmatists believe that reality is external, but can be better explained by the values of the researcher using quantitative and qualitative methods of enquiry. The decision on which method to use at any stage of the research was determined by the research question. Tashakkori and Teddlie (1998) also underscored the inductive-deductive reasoning of pragmatists, as the research starts from observations to theory using inductive reasoning and continues from theory to prediction of outcomes in a deductive approach. To further debate extreme paradigms, pragmatists embrace the use of both objective and subjective epistemologies. The study highlighted the natural appeal for pragmatism, in that it allows enquiry into the researchers' topic of choice without restriction on quantitative or qualitative methods and serves as the most appropriate paradigm for mixed methods research.

Pruyt (2006) argues that post-positivism and pragmatism do not adequately address cause-and-effect relationships in the real world, as outlined by Tashakkori and Teddlie (1998). While post-positivists view the identification of causality as ambiguous, pragmatists see causal relationships through the prism of the researchers' personal values and judgement on what is real and contributes to knowledge. The positioning of pragmatists as the only paradigm for mixing methods also falls short, as it does not capture other paradigms with structuralist views such as system dynamics. Pruyt (2006) proposed critical pluralism as a form of critical realism that lays less emphasis on ontological positioning and makes up for the short comings of pragmatism in relation to research values and causal relationship in real world. The study argued that "system dynamics does not fit well in this restrictive paradigmatic framework where objective and subjective are rigorously separated as are radical change views of social science and regulation views of social science, because of the associated irrevocable paradigm incommensurability". These views led to the adoption of critical pluralism as "a new paradigmatic framework not characterised by irrevocable paradigm incommensurability". This new paradigm not only bridges the exterme positivist and constructivist paradigms but also provides " a more acceptable home for mainstream system dynamics focussed on real understanding of the connection between causal structure, behaviour and action". Hence, critical pluralism is widely used by researchers engaging with individuals or organisations within a specific context to solve problems using their understanding of the system to identify causal relationships responsible for the systems' behaviour that can lead to changes in the mental model and outcomes of the research. Table 3.1 outlines positivist, critical pluralist, pragmatist, and constructivist paradigms.

Table 3.1: Outline of positivist, critical pluralist, pragmatist, and constructivist paradigms.

	Positivism	**Critical pluralism**	**Pragmatism**	**Constructivism**
Ontology Nature of reality	Realism Single truth	Critical realism	Pragmatist realism	Relativism Several truths
Epistemology Nature of knowledge and examining reality	Objectivism Objects exist outside the subject	Subjectivism	Objectivism and Subjectivism	Subjectivism Subject determines the reality of object
Methodology Investigation techniques	Quantitative Mainly numeric	Quantitative and Qualitative Numeric and words	Quantitative and Qualitative Numeric and words	Qualitative Mainly words
Methods Approach for data collection and analysis	Statistical analysis Used to test and generate theories	Statistical analysis and Case studies	Statistical analysis and Case studies	Case studies Used for theory generation
Causal linkages	Causes are known and precede effects	Causality is critical to understand reality	Unknown Causal Relationship	Causes and effects cannot be separated
Axiology Roles of values in investigation	Value free	More concerned about value-ladenness	Less concerned about value-ladenness	Value-bound

Source: Synthesized from Tashakkori and Teddlie (1998); Pruyt (2006); Saunders *et al*. (2009); Easterby-Smith *et al*. (2018).

3.2.2.1 Positivism

Positivist researchers believe that reality exists externally and that its properties can be measured through objective methods, rather than subjectively inferred through sensation, reflection, or intuition (Easterby-Smith et al., 2018). Positivism is mainly used by natural scientists, and Kuhn (1962) popularised positivism as a distinctive paradigm after gradually developing it for decades. Table 3.2 summarises positivist assumptions.

Table 3.2: Philosophical assumptions of positivism

- **Independence**: the observer must be independent of what is being observed.
- **Value-freedom**: the choice of what to study, and how to study it, can be determined by objective criteria rather than by human beliefs and interests.
- **Causality**: the aim of the social sciences should be to identify causal explanations and fundamental laws that explain regularities in human social behaviour.
- **Hypothesis and deduction**: science proceeds through a process of hypothesizing fundamental laws and then deducing what kinds of observations will demonstrate the truth or falsity of these hypotheses.
- **Operationalization**: concepts need to be defined in ways that enable facts to be measured quantitatively.
- **Reductionism**: problems as a whole are better understood if they are reduced to the simplest possible elements.
- **Generalization**: in order to move from the specific to the general, it is necessary to select random samples of sufficient size, from which inferences may be drawn about the wider population.
- **Cross-sectional analysis**: such regularities can most easily be identified by making comparisons of variations across samples.

Source: Easterby-Smith *et al.*, 2018

3.2.2.2 Critical pluralism

Critical pluralism, also known as critical realism, states that our experience is a sensation of what we see and not the object directly. However, critical pluralists have a realist ontological position and believe in the existence of the external world. The nature of knowledge and examining reality is derived from the meanings and explanations of the subjective position which deviates from the objective approach of positivist scholars (Tashakkori and Teddlie, 1998; Pruyt, 2006). Saunders *et al*. (2009) noted that the perspectives of critical realists are those of a constantly changing social world. Patomäki and Wight (2000) argue that critical realists view knowledge as "a social product, actively produced by means of antecedent social products—albeit on the basis of a continual engagement, or interaction, with its (intransitive) object. That is, widely different theories can interpret the same, unchanging world in radically different ways." Thus, reality is external and can be interpreted by the subject, thus making it imperfect. Causal relationships are fundamental to understanding reality, and emphasis is placed on the value-ladenness of enquiry which can lead to structural change. Critical pluralists are concerned with values and continuously engage the subject to understand reality. The aim of critical pluralist enquiry is to understand the causal structure of the phenomenon of interest and behaviour derived from the structure. The difference between critical pluralism and pragmatism is evident in the axiology, causal relationship, model suitability, research strategy, and outcome, as enumerated by Pruyt (2006).

- Values: Critical pluralists emphasise value ladenness during research. Pragmatists are not interested in value leadership.
- Causal relationship: Causality is central to understanding the behaviour of the system.
- Model suitability: Suitable models reveal insights, understanding, and learning opportunities. Pragmatists only consider model usefulness when they answer the research question and align it with the researchers' values.
- Research strategy: Critical pluralist strategies provide opportunities for changes in the structure of the system and mental models of the subjects, leading to different behaviours. Pragmatist strategies ensure a close fit with enquirers' values.
- Research outcome: Behavioural change is a research outcome of pluralist strategies, while pragmatist strategies target the realisation of desired outcomes.

3.2.2.3 Pragmatism

Pragmatism does not accept a single position in epistemology. The research questions determine the ontology, epistemology, and axiology. Pragmatism is fluid and allows researchers to move along the continuum and deploy mixed methods using both quantitative and qualitative methods (Tashakkori and Teddlie, 1998). It encourages the researcher to study the phenomenon of interest in the way that is of interest to the researcher and can impact the researcher value system positively (Saunders *et al*., 2009). The value system of the researcher determines the topic of enquiry, choice of methods, data collection, and analysis. Pragmatists have a realist ontology; however, examining reality is both objective and subjective. Researchers are indifferent to the value-ladenness of enquiry and accept only the results that satisfy their goals for the investigations (Pruyt, 2006). Hence, the research is goal-driven and guided by the research questions. The pragmatist approach to research is based on the value system of the researcher which guides the choice of topics, methods, and interpretation of results. The pragmatist is less concerned about value-ladenness during the enquiry and lacks curiosity in understanding causal structures that do not answer the research question (Pruyt, 2006).

3.2.2.4 Constructionism

The last half century witnessed the development of a new paradigm arising from the limited success of researchers applying the positivist paradigm of reality as objective and external to the researcher for observation during research. Constructivism, also known as social constructivism or interpretivism, is grounded in experience sharing and how people make sense of the world (Shotter, 1993). Constructivists argue that societal reality is constructed by people, not objects or exterior factors. General laws do not adequately explain the interactions and experiences of social groups (Easterby-Smith *et al*., 2012), see figure 3.3. Crotty (1998) stated that the assumptions of constructivism include human creation of social meanings during interaction with the world. Constructionism assumes that many different realities exist, and the researcher needs to gather multiple perspectives and experiences of diverse individuals and observers through a mixture of qualitative and quantitative methods sometimes described as triangulation. Triangsulation of similar methods, such as qualitative methods, can be used in research on social phenomena to increase the confidence and accuracy of observations made by researchers. Some researchers use triangulation in the context of different data source such as questionnaires and interviews (Bowey *et al*., 1986).

Table 3.3: Contrasting implications of positivism and social constructivism

	Positivism	Social constructionism
Researchers	must be independent	is part of what is being observed
Human interest	should be irrelevant	are the main drivers of science
Explanations	must demonstrate causality	aim to increase general understanding of the situation
Research progress through	hypothesis and deductions	gathering rich data from which ideas are induced
Concepts	need to be defined so that they can be measured	should increase stakeholder perspective
Units of analysis	should be reduced to the simplest terms	may include complexity of whole situations
Generalisation through	statistical probability	theoretical abstraction
sampling	large numbers selected randomly	Small numbers of cases chosen for specific reasons

Source: Easterby-Smith *et al.*, 2018

System dynamics studies use critical realism and pragmatism to bridge the paradigm incommensurability argument regarding the two extreme positions of positivists and constructivists. Weaver and Gioia (1994) argue that researchers must devise a means "to intelligibly unify, or at least bridge, these conflicting paradigms while still maintaining their diversity in some significant measure". These bridging strategies have led to various proposed continua to positivism, constructivism, and many other variations (Burrell and Morgan, 1979; Lane, 2001; Pruyt, 2006). Schultz and Hatch (1996) posit that the challenges encountered in conducting multiple paradigm research can be overcome by three metatheoretical positioning. The first metatheoretical position is paradigm incommensurability which is achieved by engaging with one paradigm and overlooking the other, as demonstrated by Burrell and Morgan's (1979) study, in which it is impossible for the two extreme paradigms to coexist. The second is paradigm integration, which is used to mix paradigms without recourse to the underlying assumptions. Schultz and Hatch (1996) proposed paradigm crossing as the third metatheoretical position. Paradigm crossing involves the recognition and engagement of multiple paradigms without "ignoring them as in the integrationist position, or refusing to confront them as in the incommensurability position. Paradigm crossing is achieved using the sequential, parallel, bridging and interplay approach. Unlike the sequential and parallel strategies where individual paradigm boundaries are impermeable, bridging allows transfer of findings from one paradigm to another. On the other hand, interplay allows the continual movement of the researcher across paradigms "so that multiple views are held in tension", which allows the use of multiple diverse paradigms without integration (Schultz and Hatch, 1996).

3.2.3 Thesis research paradigm using system dynamics

Research in the SCM field of supply chain management has a positivist orientation. The purpose of generalising findings from positivist studies has failed to cater to complex SCM problems. The inadequacies in the use of this approach have led to calls for a shift in paradigms to a more integrative position to foster an understanding of SC complexity. Golicic *et al*., (2005) proposed the use of a balanced perspective in choosing paradigms for SCM research that allows researchers to move away from positivism-dominant research to a more flexible use of use of quantitative and qualitative methods to facilitate deeper understanding of SC problems. Singhal and Singhal (2012) proposed broadening supply chain research to include more diverse paradigms, such as exploratory and qualitative approaches. The study also notes that SCM researchers shy away from using multiple perspectives to explore SCM issues. This could serve as a limitation in understanding and expanding the SCM field. The inability to resolve problems in operations management has led to a crisis, as stated by Kuhn (1962), and a push for a more inclusive approach to SC research. The progressive quest for knowledge in SCM includes the use of interpretivist approaches to develop theories and to explore new areas of interest. Viewing paradigms from a complimentary lens helps enrich SCM studies and build mid-range theories by integrating subjectivism in operations research (Darby *et al*., 2019). The predominance of positivist SCM research has been shown to prevent the growth and acceptance of the field, necessitating the use of other approaches (Towers and Chen, 2008).

In support of the argument for the expansion of SC research away from a positivist focus, and to address the flaws of positivism, this thesis applies a multiple integrative system dynamics paradigm to understand the causal behaviours in dynamic supply chains, where pluralist methodology is deployed to build system models and examine SC issues with different actors across multiple organisations (Pruyt, 2006; Adamides *et al*., 2012; Tomoaia-Cotisel, 2018). Systems dynamics involve the use of multiple paradigms, necessitating the need to resolve paradigm incommensurability by developing more integrative approaches. A system dynamics integrative approach was used to understand the context of SCI and performance. SCM involves many organisations and actors with different experiences. Positivism deals with objective truth and does not consider the experiences of system actors. The outcome of positivist research is mainly generalisation which is inappropriate for understanding contextually focused research which is mainly constructivist in nature. Understanding how partners within a network can integrate their operations and processes to achieve the common goal of improved performance calls for the exploration and understanding of the underlying causal structure and how the change in structure leads to a behaviour that improves performance. Each organisation has a method for measuring performance. When organisations come together to serve the patient as the end-user, the need of the customer takes precedence and performance of the individual organisation, and the network must align with the customer needs. System dynamics uses the constructivist paradigm to unravel the experiences of different stakeholders within a supply network and the positivist paradigm to model and simulate the systems' performance by engaging in paradigm crossing (Pruyt, 2006; Tomoaia-Cotisel, 2018). This thesis adopts the interplay paradigm crossing strategy to enable the fluid movement of the researcher across boundaries of multiple paradigms to allow "cross-fertilization between the ever-growing number of paradigms, while maintaining diversity" (Schultz and Hatch, 1996). The choice of interplay paradigm crossing over incommensurability and pragmatist integration allows the use of multiple paradigms to address the underlying theoretical problems (Tomoaia-Cotisel, 2018). Finally, adopting the system dynamics integrative paradigm allows the use of multiple methods to examine medicine SCs, which can lead to the development of new knowledge and understanding of how integrated networks can improve performance.

3.3 Research approaches

Some research approaches have distinct philosophical assumptions about ontology and epistemology, making them more appropriate paradigms, while less ontological and epistemologically distinct approaches are considered as a school of thought or meta-methodologies (Easterby-Smith *et al.*, 2012; Easterby-Smith *et al.*, 2018). Engagement with research phenomenon can be 'detached' where the researcher strives to be independent from the people and processes of the topic of research or 'engaged' with the people and processes being investigated, yielding positive value in interaction with the social systems phenomenon such as complex organisations (Easterby-Smith *et al.*, 2018). The three main research approaches are outlined below and shown in (Figure 3.1).

- Deductive research follows a conscious direction from general law (theory) to a specific case (facts). Deductive reasoning is mainly rooted in the natural sciences test theory which starts by establishing causal relations between the variables of interest. A deductive researcher is independent of the phenomenon and can physically observe the outcome of an enquiry. Deduction aims to generalise the findings by using a sample size to statistically determine the occurrence and control research output (Saunders *et al*., 2009).
- The inductive approach uses the direction of a specific case (fact) to generalise the law (theory) (Taylor *et al.*, 2002). Induction is used for theory building by engaging subjects to understand their experiences. Social scientists critical of the deductive approach engage in inductive reasoning by trying to understand the reasons behind observed behaviours before developing theories around the social world (Saunders *et al*., 2009).
- The abductive approach is rooted in the belief that the research approach should be continuous, and not just theory to facts and facts to theory. The abductive approach is also suitable for new phenomena (Kovács and Spens, 2005).

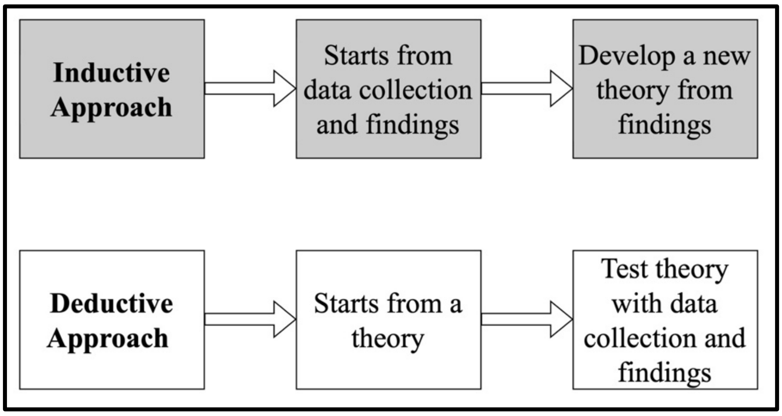


Figure 3.1: Inductive and deductive approach in theory development and use

Source: Saunders *et al*. (2009)

Saunders *et al*. (2009) cautioned that deductive and inductive approaches must be viewed as fluid which can lead to a combination of both approaches for exploring a research topic. This aligns with the system dynamics approach where deductive and inductive approaches are used to solve problems. All three approaches can be used depending on the underlying assumptions of the SD model. The approach is usually deductive for positivists and inductive for constructivists. Intermediary paradigms such as critical pluralists and pragmatists engage in deductive and inductive logic to conduct SD studies. Usually, SD modelling begins by engaging stakeholders to solve a specific problem and building mental models using an inductive approach, as shown in Figure 3.1. Mental models are used for modelling and simulations in a deductive approach to understand the behaviour of the system and facilitate the learning that leads to changes in behaviour (Pruyt, 2006; Sterman, 2001).

3.3.1 Thesis research approach

This research is concerned with the integration of essential medicines SCs and the factors that improve SCP. Understanding the context of the research and the experiences of SC actors is important for learning and developing a general understanding of SCI. Inductive and deductive approaches were used in this thesis, as demonstrated in the system dynamics methodology (Sterman, 2001; Pruyt, 2006; Tomoaia-Cotisel, 2018). Inductive logic leads to the development of micro-theories which serve as inputs for deductions in the simulation phase (Pruyt, 2006). The aim of this research is to build a mental model of SCI which requires inductive logic by engaging SC stakeholders to reveal their knowledge of the system for a better understanding of SCI. The validated mental model which is a micro-theory of SCI, was used for deductive simulations to understand the behaviour of the real system.

3.4 Research strategy

The research strategy is an outline for investigating a phenomenon by seeking and evaluating available evidence (Malhotra, 2017). According to Johannesson and Perjons (2014), "research strategy guides a researcher in planning, executing, and monitoring the study". The research strategy is a high-level plan that requires a detailed research method to execute. Research methods address the specifics of data collection and analysis to support the implementation of the strategy. This definition shows that a researcher must prepare a strategy and detailed research methods before engaging in the research process. The interdisciplinary nature of SCM has led to the use of various methods to explore the problems of complex SCs and to design strategies for SCM research. Kovács and Spens (2005) reviewed SCM articles from 1998 to 2002 and found the dominance of deductive research over inductive and abductive research in theory-building. Seuring *et al.* (2005) reviewed the different research strategies used in SCM according to the methodologies deployed, namely theory building, surveys, case studies, action research, and modelling. The choice of an appropriate strategy depends on the purpose of the study and whether it is suitable, achievable, and ethical. A suitable strategy should help answer the research questions. Although an experiment can reveal the reasons behind an occurrence, it cannot explore complex relationships, as in the case study. A feasible strategy should consider all the resources needed by the researcher, such as access to information, funds, timeframe, and materials. Ethical considerations must be considered in the research strategy to keep records confidential and not harm individuals, experimental animals, and the environment (Johannesson and Perjons, 2014). Saunders *et al*. (2009) highlight that it is naïve to consider research strategy as a deductive or inductive approach, and argue that strategies can be mixed. Research strategies included experiments, surveys, case studies, action research, grounded theory, ethnography, and archival research. The next section presents the case study as the selected strategy for this thesis and introduces different types of case study strategies.

3.4.1 The case study strategy for the thesis

The case study strategy examines the phenomenon within its context in real life, where there is no clear boundary between the context and phenomenon (Yin, 2015). One of the characteristics of the case study is the presence of multiple variables of interest which can lead to the use of various combinations of data techniques during data collection, necessitating the need for triangulation of data. Quantitative survey questionnaires can be triangulated using qualitative interview data (Saunders *et al*., 2009; Yin, 2015). The case study tries to answer research questions that deal with the 'how' and 'why' a phenomenon operates and considers questions that require in-depth explanation of the phenomenon. Apart from examining real-life phenomena within its context, the use of theoretical propositions as a guide for data collection and analysis distinguishes the case study strategy from others. There are two types of case study strategies: a single case study and multiple case studies (Yin, 2015). The single-case strategy can be used to explore exclusive or rare cases or to examine research questions that have not been investigated by previous researchers. The case may be chosen because it is uncommon or common, but is used to explore atypical questions (Saunders *et al*., 2009). The need to compare and generalise the findings leads to the choice of multiple case studies. Yin (2015) also classified case studies according to the unit of measurement as holistic and embedded to represent single and multiple units, respectively (Table 3.4).

Table 3.4: Types of case study designs

Type of Case Study	Holistic design (single unit of analysis)	Embedded design (multiple units of analysis)
Single case	Type 1	Type 2
Multiple case	Type 3	Type 4

Source: Yin (2015)

This thesis adopts a case study strategy in recognition of the need to include an inductive approach in the field of SCM, as opposed to the dominant deductive approach. The use of the case study strategy for this thesis will allow the examination of the real life of essential medicine public health SCs, where there is no clear boundary between SCs and SCI as a phenomenon of interest. The variables in this research are multiple which necessitates the use of multiple techniques to collect and analyse data. This thesis uses a survey and interviews to obtain information that can be triangulated to explain, compare, and generalise performance across the essential medicine SCs in Kaduna state. It will also help answer the thesis research questions on how SCI improves medicine availability performance, provide a means of obtaining in-depth explanations on the factors that enable or hinder medicine availability, and provide clarity on the types of performance derived from SCI practices. This thesis examines the phenomenon of SCI leading to improved medicine availability. The essential medicine SC is not a rare case, as all hospitals in Kaduna State operate an essential medicine revolving fund program leading to the choice of a multiple case study for the thesis. This thesis explores the essential medicine SC in each organisation as a single unit of analysis because the essential medicine SC is a single program anchored by the pharmacy department, even though the operations involve some actors from accounts, administration, procurement, and nursing departments. The reporting, implementation, and monitoring of the program are under the purview of the Pharmacy Department. These considerations informed the choice of a Type 3 holistic case study design for this thesis.

3.5 Research methodology

The research paradigm determined the methodology of the study to be quantitative or qualitative (see Table 3.1), as described in Section 3.2.2. The mixing of methods gives rise to what is commonly known as a mixed-method approach. In exploring the difficulty for researchers to match paradigms to methodology and methods, Mackenzie and Knipe (2006) proposed the decoupling of researchers from research methods to allow the adoption of the appropriate methods in examining the phenomenon of interest. They argue that restricting research paradigms to mono-methods can be limited and advocated for the use of mixed methods for the robustness of research. The pure use of either quantitative or qualitative methods is almost impossible when examining the social world. This position was reechoed by Guba and Lincoln (2005) in support of combining quantitative and qualitative methods. Although Creswell (2009) identified pragmatism as the philosophy of mixed-methods researchers, other studies have argued for the mixing of elements from different paradigms to attain the best outcomes (Guba and Lincoln, 1994; Schwandt, 2000; Guba and Lincoln, 2005). Since mixed methods challenge mono-method research which is the dominant method of conducting research in social sciences (Timans *et al*., 2019), researchers have developed models for mixed-method phenomenological research (MMPR). The evolution of MMPR is due to the need to use experience in generating, testing, and generalizing theories. There is an increased focus on phenomenological research, search for unforeseen findings and triangulation of information or cross-validation (Mayoh and Onwuegbuzie, 2013). According to Johnson *et al*. (2007) "Mixed methods research is the type of research in which a researcher or team of researchers combines elements of qualitative and quantitative research approaches (e.g., use of qualitative and quantitative viewpoints, data collection, analysis, inference techniques) for the broad purposes of breadth and depth of understanding and corroboration". Johnson *et al*. (2007) argued that the mixed method approach provides the most comprehensive and beneficial outcome of the research. The classification of pure qualitative to pure quantitative is a continuum of qualitative mixed, pure mixed, and quantitative mixed (Figure 3.2). The qualitative mixed method is a dominant qualitative method, whereas the quantitative method dominates the latter. The pure mixed approach has equal application of both qualitative and quantitative methods.

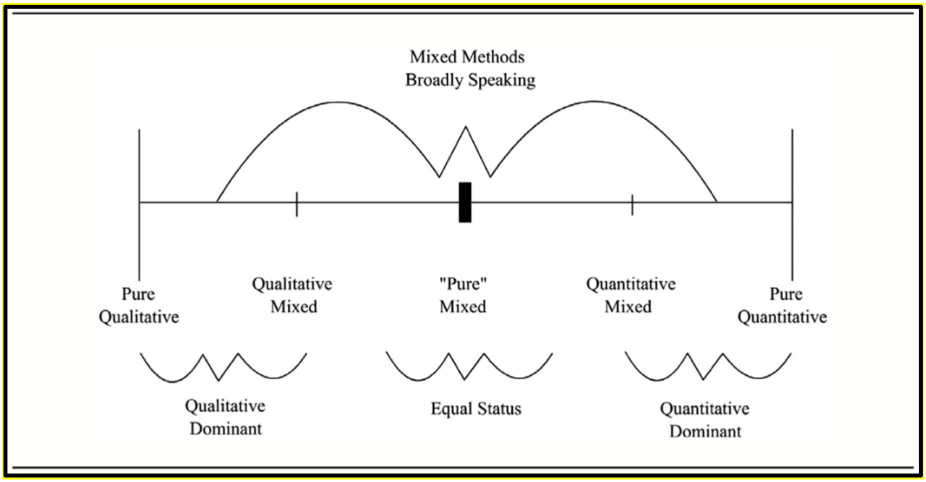


Figure 3.2: Graphic of the three major research paradigms, including subtypes of mixed methods research

Source: Johnson *et al.,* (2007)

Creswell (2009) proposed three designs of mixed methods: sequential, concurrent, and transformative strategies.

- Sequential mixed methods: Quantitative methods are used to build on qualitative methods to generalise findings; for example, large population surveys can be used to build on interviews. A qualitative method could also be used to gain a deeper understanding after the application of a quantitative method. This involves the use of interviews after the surveys to gain a better understanding and construct meanings from the research perspective.
- Concurrent mixed methods: This involved the synchronised use of both quantitative and qualitative methods during data collection and analysis. For example, a quantitative survey questionnaire can precede an open-ended question to gain a deeper understanding of the phenomenon, while the survey deals with the effects.
- Transformative mixed methods involve the use of a theoretical perspective to collect data using sequential or concurrent methods.

System dynamics methodology uses a combination of quantitative and qualitative methods to build models for undersanding complex problems. The process of mixing in SD starts with the mixing of paradigms through incommensurability, integration, and paradigm crossing (Pruyt, 2006; Adamides *et al*., 2012; Tomoaia-Cotisel, 2018). The use of these metatheoretical positions allows for the adoption of a suitable mixing strategy based on the purpose of the modelling. This thesis adopts the system dynamics integrative paradigm which uses qualitative and quantitative methods to achieve its research aim. The choice of paradigm crossing as a bridging approach for this study can be realised by sequential, parallel, bridging, and interplay strategies, allowing the use of pluralist methods (Schultz and Hatch, 1996). This requires the researcher to be skilled in using quantitative and qualitative methods. Pruyt (2006) developed a research cycle that shows the stages of mixing quantitative and qualitative methods in SD studies (Figure 3.3). This model was adapted and used in this study.

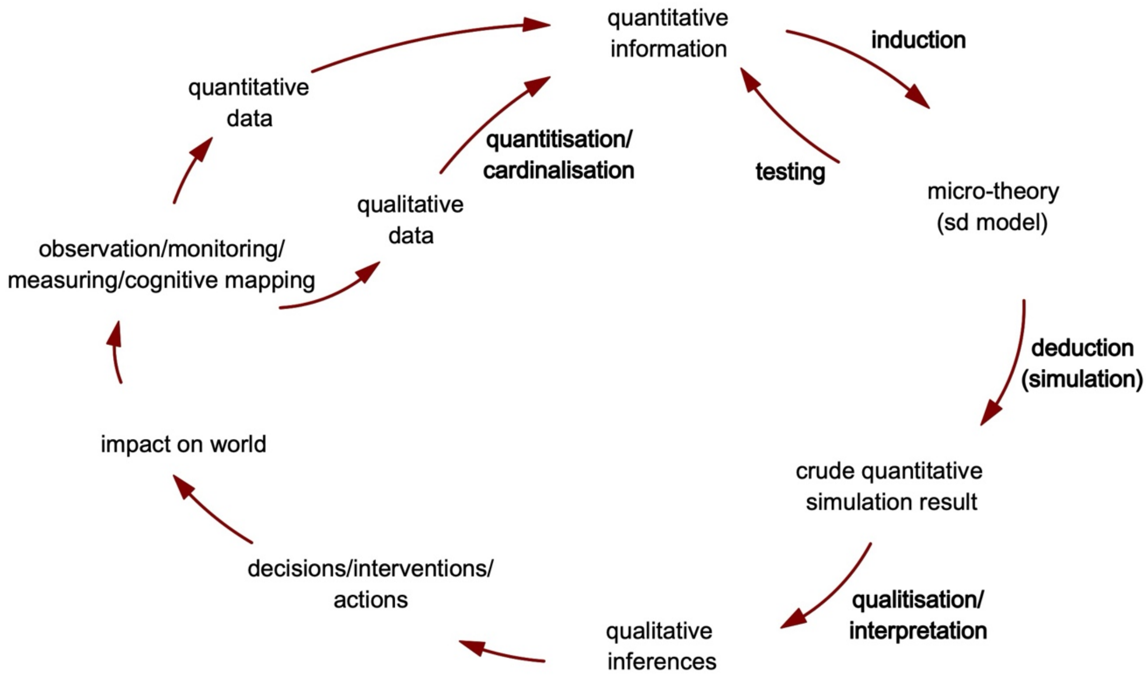


Figure 3.3 The system dynamic research cycle

Source: Pruyt (2006)

3.5.1 Simulation in healthcare supply chains

Shannon (1998) defines simulation as "the process of designing a model of a real system and conducting experiments with this model for the purpose of understanding the behaviour of the system and /or evaluating various strategies for the operation of the system". Simulation is a method that is used when it is impractical to observe a phenomenon in real life. Apart from enabling the identification of the variables crucial to system performance, simulation permits the observation of the system to identify constraints in the flow of products, materials, and information, and test policies for improving the flows, thereby enhancing the system performance. Maidstone (2012) identified three main methods used in simulation modelling, namely discrete event simulation, agent-based modelling, and system dynamics modelling. Brailsford *et al*. (2009) reviewed literature from 1952 to 2007 and found an increasing trend in the use of qualitative models such as discrete event simulation.

The study identified categories of simulations to include discrete-event, system dynamics, agent-based, distributed, and Monte Carlo simulations. Almagooshi (2015), notes that more researchers are engaging in exploratory modelling using advanced software for discrete and agent-based models. The review also pointed out the poor representation of system engineering and system dynamics models. Maidstone (2012) gave some definitions of the three methods as follows.

- Discrete event simulation involves modelling entities as they pass through different stages at different times. This could be modelled as a patient passing from one station in the hospital to another in a queue-and-server model where the patient queues to access service from the healthcare giver. Discrete simulation is used to model a part of the system which involves processes that involve queues. The simulation model was stochastic, yielding different results for each run.
- An agent-based simulation uses autonomous agents to model a system with stochastic outcomes using a bottom-up approach. The model is time consuming to build and run the simulations.
- System dynamics uses stocks, flows, and delays to model a system rather than an individual in the system using a top-down approach. The SD was used to model the entire system with flows. The simulation model was deterministic, yielding the same result for each run. Hence, the SD model required only one run.

Choosing a suitable method for simulation requires consideration of the nature of the problem and the target objectives. Comprehension of the system and simulation techniques helps the modeller achieve simulation objectives (Maidstone, 2012). These three methods have been used in healthcare SC modelling. Discrete event simulation has been used to reduce lead time and improve warehouse decision making through lean techniques (Abideen and Mohamad, 2021). The behaviour of agents in a pharmaceutical SC has been explored using agent-based modelling to determine the practice towards agile, lean, and green logistics practices (Pourghahreman *et al*., 2018). Rosales *et al*., (2020) used system dynamics simulation to demonstrate the benefits of inventory visibility in coordinating joint replenishment between partners. Other studies have examined the reduction in medicine stockouts in healthcare SCs (Kumar and Kumar, 2015; Bam *et al*., 2017). The next section details the choice of modelling method used for this thesis and the rationale.

3.5.2 System dynamics integrative methodology for the thesis

This thesis uses Pruyt's (2006) mixed method in Figure 3.3 in Section 3.5, and Tomoaia-Cotisel's (2018) integrative methodology in figure Figure 3.4 below to model the SCI of public healthcare SCs using interplay-paradigm crossing approach (Tomoaia-Cotisel, 2018). The system dynamics simulation method is used in this thesis to examine the entire network of public healthcare SCs. SCI is a strategic organisational decision which is the main strength of the SD method, as it models the entire system at a strategic level using flows, stocks, and delays, with no consideration for individual actors within the system (Borshchev and Filippov, 2004). The problem of medicine stockouts and investigating SCI to improve overall system performance occurs at the strategic level of every organisation and involves the observations of stock and flows between manufacturers, suppliers, and healthcare service delivery points. The delays that can arise from the system constraints can be modelled with SD, and policies to improve flows and reduce delays can be tested to improve decision making. SD is suitable for this thesis as it allows for continuous observation of the entire SC system over time, unlike discrete events, where the focus of the model is on queues at specific times and nodes. SD modelling involves the use of accurate quantitative data in a global network (Borshchev and Filippov, 2004). Although the use of aggregates and lack of individuality are appropriate for SD models, the provision of adequate data is critical to understanding the behaviour of the system and testing policies for improvement.

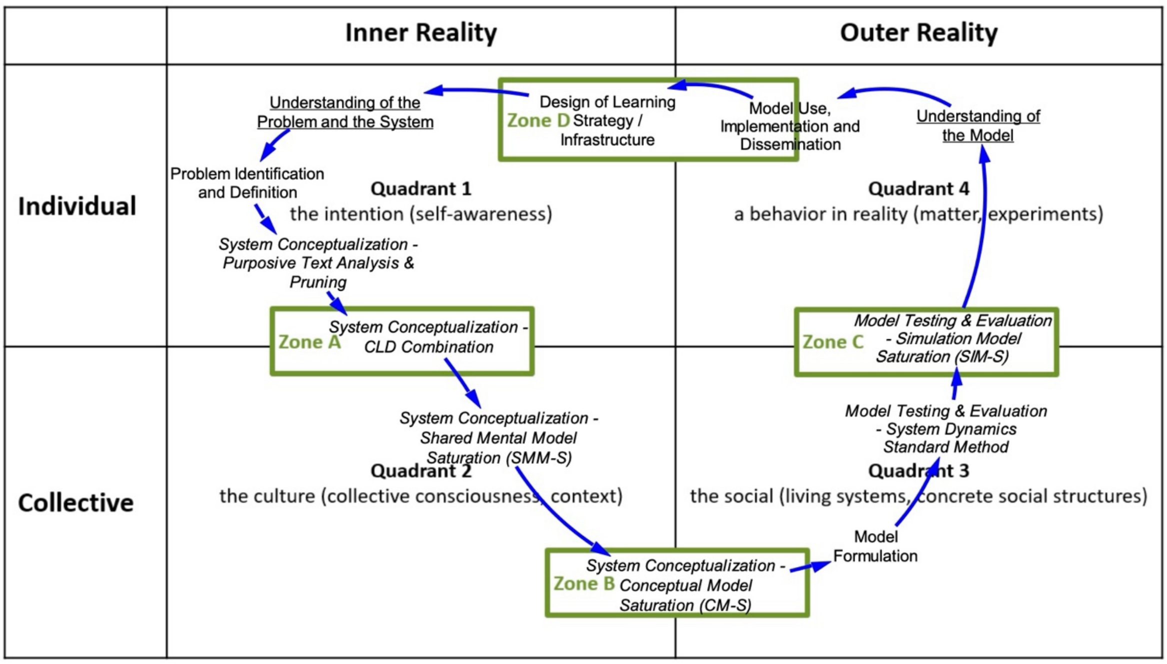


Figure 3.4: Integrative methodology for system dynamics modelling

Source: Tomoaia-Cotisel (2018)

The two models were used to conduct the modelling and demonstrate the interplay paradigm-crossing strategy of the SD integrative methodology. The transition zones of paradigms are the convergence points of multiple paradigms that the researcher cannot differentiate between (Gioia and Pitre, 1990).

3.6 System dynamics methodology

The SD methodology uses the mixed method systems approach of defining problems qualitatively and building simulation models quantitatively to address complex problems such as SCI in healthcare settings where multiple stakeholders interact to provide services, which can lead to unintended effects (Wolstenholme and Coyle, 1983). Understanding how system actors think about problems can be visualised using mental models to help interpret changes arising from decision points and feedback. These mental models assist in developing and simulating policies that can withstand the disruptions caused by system changes (Sterman, 2000). The provision of medicines in hospitals for the treatment of patients is a dynamic system, as medicines are expected to be available when patients need them and not in excess which can lead to obsolescence. Hospital medicine stock levels increase after procurement, and are depleted upon sales, shrinkage, and expiries. Distributor stock levels increases after procuring from the manufacturer and decreases after sales to hospitals. The manufacturer stock level increases after manufacturing medicines from received raw materials and depletes upon sales to distributors and hospitals. Cash also accumulates after sale to patients and is depleted after payment to suppliers. Account receivables increase when medicines are sold on credit to customers and decrease when customers make payments. Account payables increase when suppliers deliver medicines to hospitals and decrease when they receive payment for supplies. These six levels of accumulation determine the availability of medicines at hospitals for customer service delivery. The characteristics of a dynamic system include the presence of levels, rates, and delays, as described for the EMs system (Wolstenholme and Coyle, 1983; Sterman, 2000). Some of the rates that determine availability include procurement, payment, sales, expiries, shrinkage, and cash collection. The delays that can arise from operational activities also affect how the system can sense and respond to challenges in medicine availability (Coyle, 1997).

3.6.1 Pre-planning for system dynamic modelling and simulation

The pre-planning phase for SD modelling EMs programs was conducted using qualitative key informant interviews to understand the integration levels and SCI themes fundamental to improved MFR in five cases. The selection of fast-moving EMs which are more prone to stockouts was conducted by reviewing the prescriptions and procurement data of the organisations. A group survey was completed in each organisation to assess baseline MFR and medicine availability, in line with Pruyt's (2006) first stage of SD research which comprises the collection of qualitative and quantitative data.

3.6.2 Stages of system dynamics modelling and simulation

The dynamic modelling and simulation stages were developed based on the works of Coyle (1997), Sterman (2000), and Pruyt (2006). The first phase is to understand the problem and map the system to identify the actors and system elements responsible for the observed behaviour. This phase was achieved by engaging systems actors to share perspectives on supply chain operations and the factors contributing to the availability of medicines to define model boundaries. Phase two allowed for a full description of the working system using causal loop diagrams to develop the conceptual model for each case. The third phase was model building using CLDs and iterative simulation of the model to mimic the behaviour of the supply chain system. Testing, analysis, and validation were conducted using quantitative data from a case study in the fourth phase. The model was compared with the reference mode for behavioural replication. Policies that improve the MFR were tested and accompanied by a sensitivity analysis of decisions on the behaviour and structure of the network in phase five. The robustness of the policies was tested and interactions between policies were observed for synergistic or antagonistic effects. The modelling session was complemented by continuous testing and revision of the developed SCI simulation model. The final phase was the implementation of policies in the case study to observe the similarities and differences with the designed simulation model for improving the EMs fill rate (Figure 3.5).

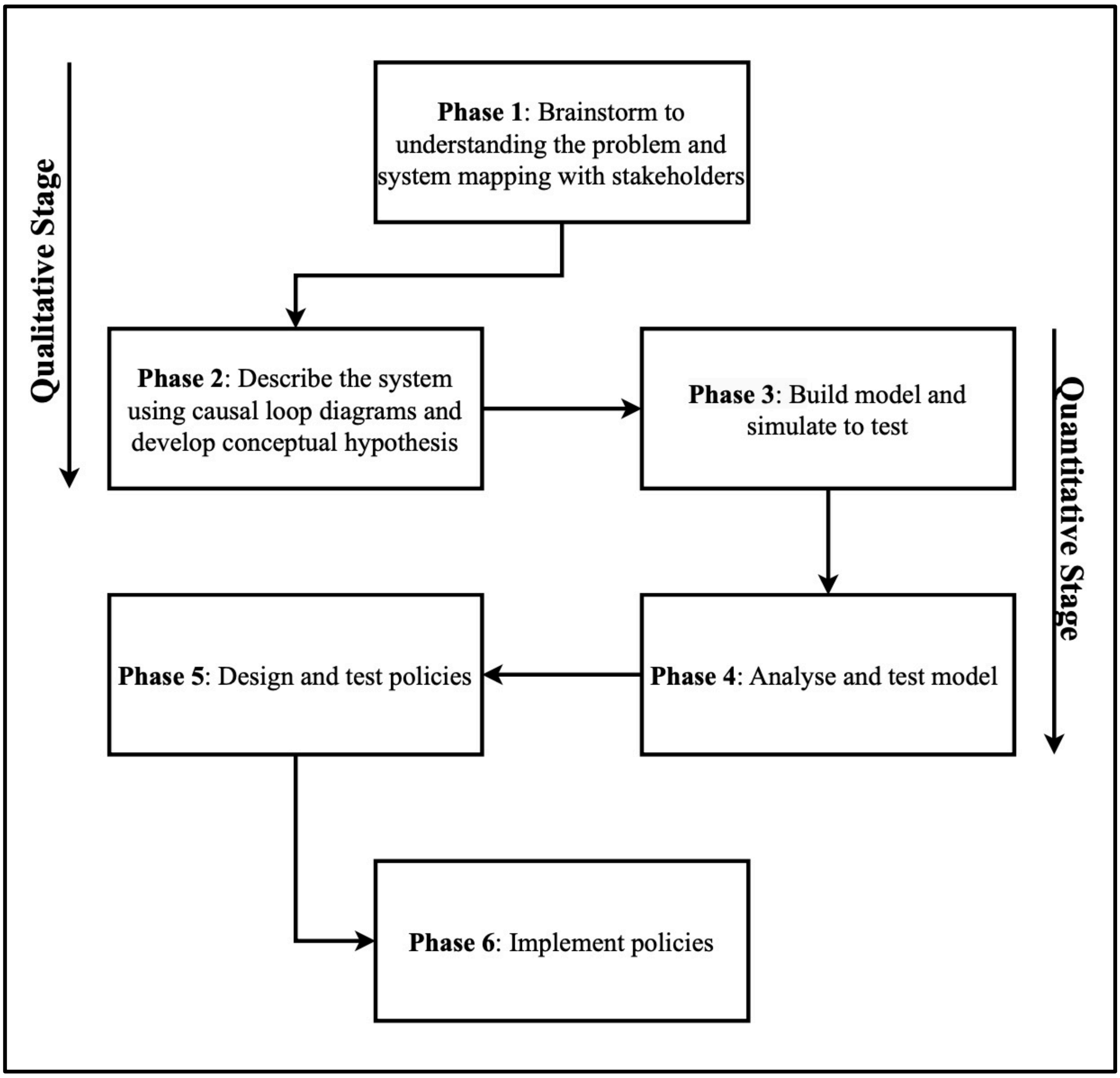


Figure 3.5: System dynamic modelling and simulation stages

Source: Adapted from Coyle (1997), p. 11; Sterman (2000), p. 86.

The theoretical model of the integrated supply chain was analysed (Figure 3.6) to determine the effects of the eight policies on increasing MFR. Policies that enhance internal integration reduce shrinkage and manage credit sales for internal customers. Procurement and payable payment policies support external suppliers and customer integration. Cash collection and account receivable policies determine the level of cash flow integration. The information-sharing policy regulates all network communication and operations. The replenishment policy is network-oriented and controls order fulfilment from suppliers to hospitals which further determines the MFR for essential medicines. The full analysis is presented in Section 6.13.

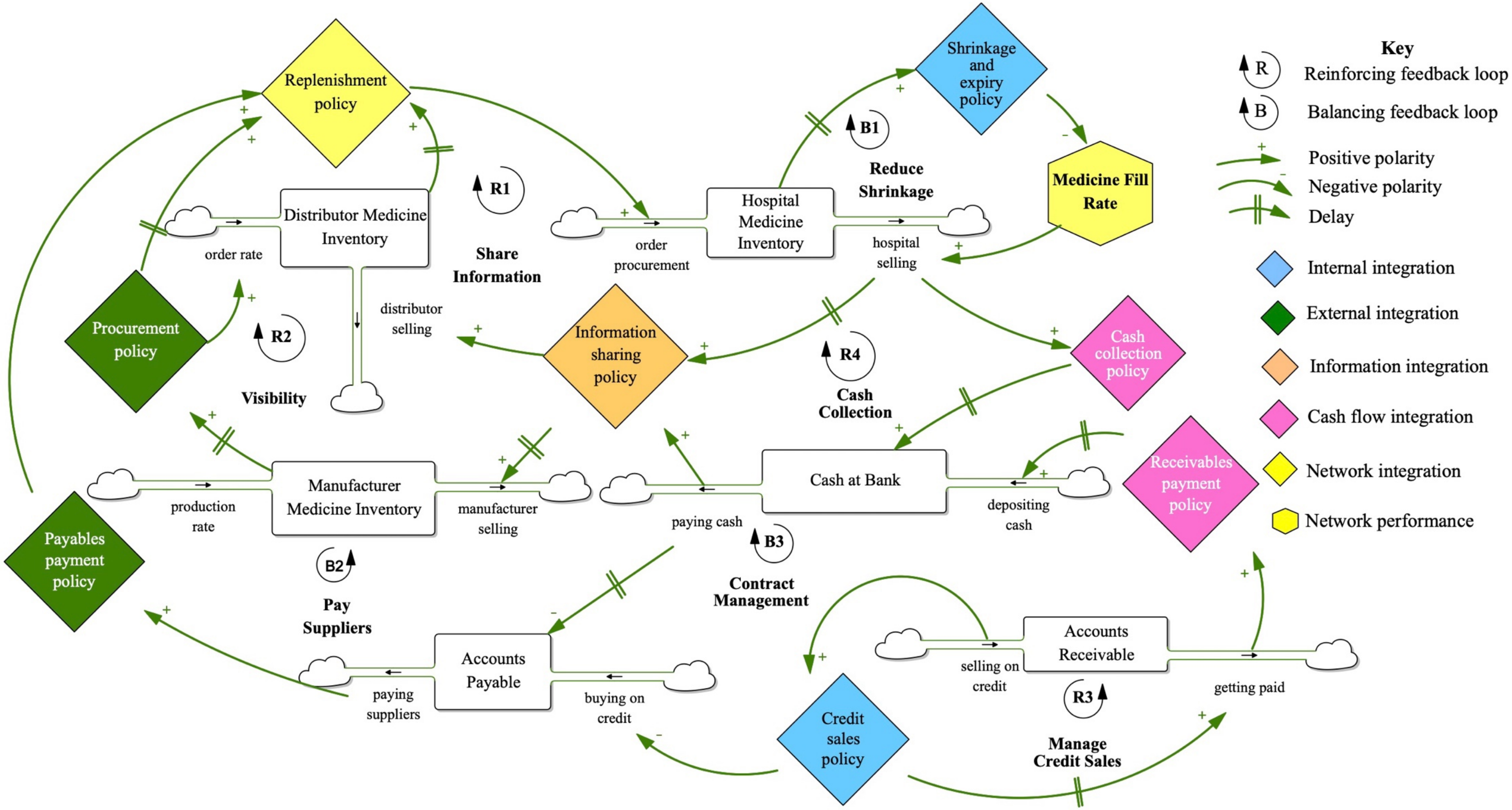


Figure 3.6: Theoretical model of essential medicines ISC

The reinforcing loops of R1, R2, R3, and R4 were balanced with the B1, B2, and B3 loops to improve MFR. Focusing on reducing shrinkage, paying suppliers and contract management minimise EMs stockouts. The essence of SCI is to increase the medicine fill rate which relies on the availability of medicines in hospitals for patient care and improving network performance.

3.7 Research design

This research design began with a critical literature review of the concepts of supply chain management and supply chain integration to identify gaps in the literature. System dynamics theory was used to ground the theoretical framework. The design was divided into three phases, as shown in the research design roadmap (Figure 3.7).

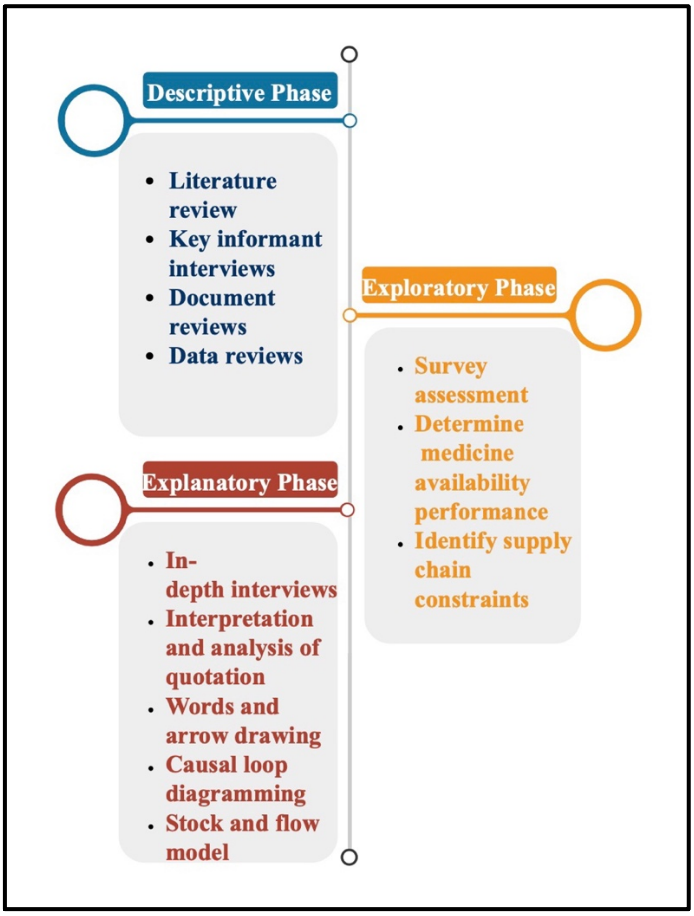


Figure 3.7: Research design roadmap

3.7.1 Exploratory phase

Key informant interviews and document reviews were conducted to gain new insights into the SCI levels to improve MAP and address the objectives of this study.

3.7.2 Descriptive phase

Survey of public healthcare supply chains to identify integration capabilities in healthcare SCs that impact MAP and reduce medicine stockout in line with objective two of this study. This phase uses the Global Health Supply Chain Maturity Model to measure SCs and determine the MAP level. The results from this phase help develop a protocol for in-depth interviews in the explanatory phase (Tashakkori and Teddlie, 1998).

3.7.3 Explanatory Phase

The use of in-depth interviews and rigorously interpreted quotations to assess the perceptions of system operators and draw mental models of their perception of system structure, feedback, and delays in providing medicines to patients. Participants' mental models were used to reinforce survey output (Creswell and Clark, 2007). The Causal Loop Diagrams (CLDs) of mental models were refined to develop a dynamic theory of MAP to fulfil objective three. Design of a three-tiered integrated model of the DRF program using CLDs. The iteration and refining of the integrated model for the simulation of MAP improvement policies are shown in the mixed method framework (Figure 3.8).

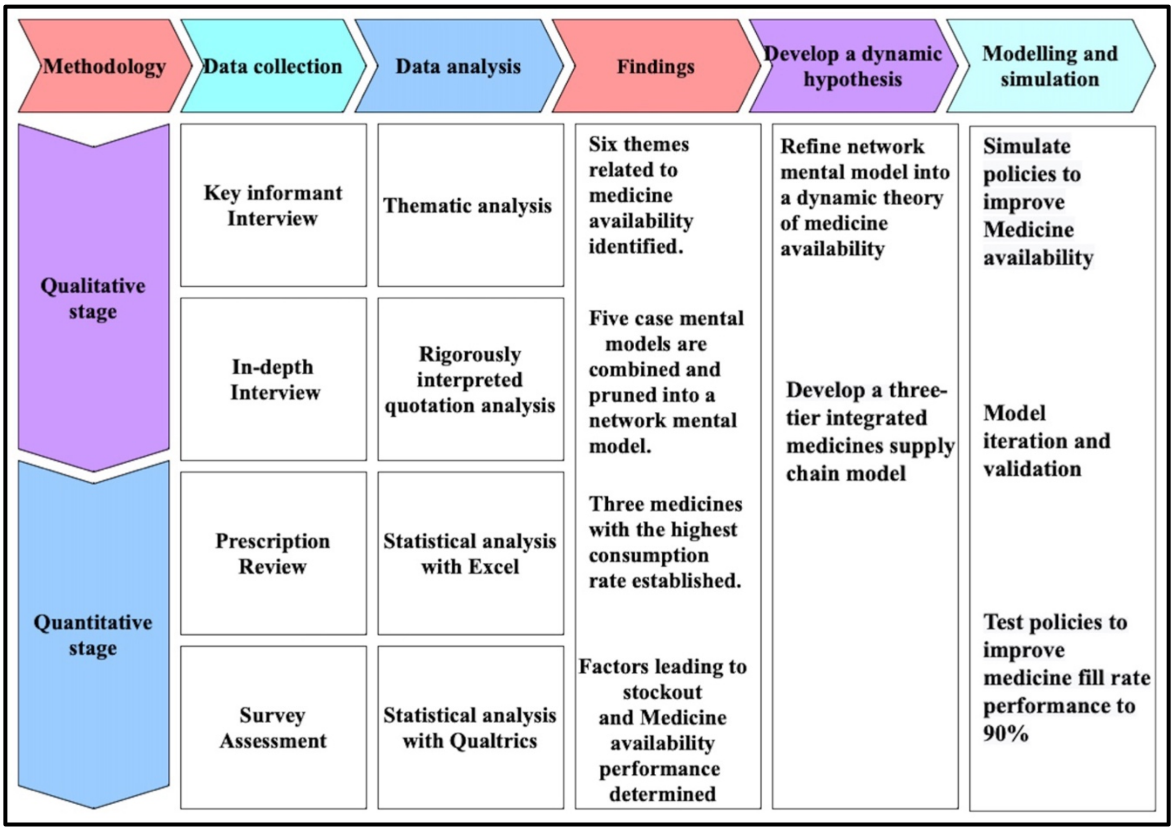


Figure 3.8: Mixed-method framework for improving medicine fill rate performance

3.7.4 Rationale for mixed method approach

This study used quantitative and qualitative methods to gain deeper insights into revolving fund healthcare SCs medicine stockouts to explore how SCI improves medicine availability and fill rate performance, as shown in the mixed-method framework in figure 3.5. First, conducting key informant interviews with selected SC managers provides an understanding of the levels of integration and medicine availability by analysing the DRF medicine acquisition processes to address the objective one. The interviews were recorded with notetaking, transcribed, and analysed using thematic analysis. Thematic analysis from the interviews identifies the categories of information on processes leading to medicine stockouts. Information on demand forecasting, procurement, warehousing, delivery of medicines, and stockouts was collected and analysed to understand how medicines flow through the systems. Second, prescription review identified the classes of essential medicines with high to moderate consumption rate used in the SCs towards improving availability fulfils the objective one. Prescription reviews help identify essential medicines that are prone to stock-out from a high consumption rate. Statistical analysis of prescriptions provides the frequency of medicine availability across cases and serves as a reference mode for validation of the model to achieve objective four.

Third, administering an SC survey assessment to the DRF members in the five cases enables the identification of the DRF operational factors and constraints leading to medicine stockouts to address objective two. The survey collected information on supply chain activities, from order management to fulfilment. Statistical analysis of the survey identified patterns of factors responsible for medicine stockouts and identified problem areas across SCs. Fourth, conducting in-depth interviews with internal and external SC stakeholders achieves objective three and four. The in-depth interviews gathered participants' perceptions of the DRF operations which provided the mental model of medicine availability processes and the structures and feedback leading to stockouts. The interviews were recorded, transcribed, and prepared for quotation analysis by removing conversation fillers, repeated words, and phrases before analysis using rigorously interpreted quotation analysis (Tomoaia-Cotisel *et al.*, 2022) to draw word and arrow diagrams. Open-text quotation analysis of transcripts provides a grounded theory approach to data analysis for developing a theory of medicine availability. The words and arrow diagrams were used to draw causal loop diagrams of participants' mental models, followed by combining and pruning causal loops to develop the network model and a dynamic theory of medicine availability to achieve objective three. Finally, a stock and flow model of an integrated three-tiered SC was designed using Vensim PLE Plus to simulate policies that increase medicine availability and the fill rate in the network. The stock and flow model helps to quantify and measure the fill rate performance and policies that improve the availability of medicine while reducing stockouts. The ISC model was used to validate the dynamic theory of network medicine availability and address objective four of this research. The mixed-method approach provides a unique opportunity for data triangulation (Yin, 2015) which supports the generalisation and transfer of findings from this research (Kopainsky and Luna-Reyes, 2008; Ivankova and Wingo, 2018).

3.7.5 Pilot case study

Conducting a case pilot study before the main study helps to identify real-life problems that can arise during the research and develop a strategy to mitigate these problems. According to Yin (2015), the pilot case can be selected based on "convenience, access, and geographic proximity". The use of the pilot to observe responses from the field helped the researcher redraft the content of the interview protocol in the case of qualitative interviews (Yin, 2015). A pilot case study was conducted to test the reliability and content validity of the survey questionnaire (Polit and Beck, 2006). A single-case pilot study was selected for this thesis, using the maternal and neonatal health supply chain of the Kaduna State Health Supplies Management Agency. The pilot study was conducted in July 2020 at the beginning of the covid pandemic. The maternal and neonatal health supply chain is one of the nine parallel SCs in Kaduna that procures and distributes essential medicines free of charge to pregnant women and children. Unlike the revolving fund chain which sells medicines at cost plus mark-up price, free medicines are dispensed at no charge to patients in hospitals. The two SCs have similar but independent operations, with separate procurement, warehousing, inventory management, and distribution processes. These similarities in structure and operations make maternal and neonatal health supply an ideal pilot case study. The selection criteria were based on convenience, as the researcher had personal contact with the SC operators which also made information readily available. The location of the maternal and neonatal operation site is in the Kaduna metropolis and is easily accessible. A pilot case study was conducted to ensure the validity and reliability of the protocol (Perry, 1998; Abushaikha, 2014).

3.7.5.1 Qualitative pilot study

The key informant interview protocol was used to administer semi-structured interview questions to three participants from the Kaduna State Maternal and Neonatal Medicine

Program. The semi-structured interview is appropriate for this study to explore participants' thoughts and feelings about SCI and performance by collecting open-ended causal information that will help build mental models of their operations. The participants were SC practitioners with extensive experience in the operations of maternal and neonatal medicine programs. The SC was chosen because of the convenience of location and access to the information required for the study. The interviews were recorded and transcribed using Otter software. Responses from the pilot study were used to fine-tune and restructure the interview protocol to ask clearer questions during the main study. The questions were centred around medicine demand planning, procurement, warehousing, inventory management, distribution, and medicine stockouts. The outcome of the pilot revealed the need to expand the questions to include SC relationships, teamwork, information sharing, and performance management. The framing of the questions was adjusted to be more open ended.

The pilot results highlighted the need to stagger the key informant interview into two stages to enable the participants to have sufficient time to answer the questions, as this was not possible in one session. Additionally, there was a need to consult documentation to answer questions on medicine consumption as the information was not readily available. Questions on operations such as forecasting, ordering, and warehousing appeared to be easier for the participants compared to questions on specific essential medicine consumption patterns which justifies the need to consult documents for accuracy. The insights gained from the pilot led to the design of an in-depth interview protocol for this thesis (Appendix V). In-depth interviews are necessary from a systems perspective to understand how the SC network operates to provide medicines to patients. The pilot was important as this study started in 2020 at the beginning of the COVID-19 pandemic, and adjustments were necessary because healthcare practitioners were overwhelmed with the treatment of patients and risk of exposure to the disease. Face-to-face interviews were restructured into telephonic sessions. Interviews were scheduled with the participants at their convenience. The difficulty in recruiting participants during the pandemic prepared for the expectations of timing and delays which were anticipated from the pilot study. The outcome from the pilot also helped prepare for the quantitative virtual maturity model session, as there was a continuous change in the COVID-19 protocol restricting movement and gathering of individuals in a location which could disrupt the initial face-to-face plan. Questions from the pilot study were expanded from eight (8) to fourteen (14) and the language was tailored to evoke causal statements that would explain medicine stockouts.

3.7.5.2 Quantitative pilot study

Survey tools were reviewed to select an appropriate instrument to measure the performance and medicine availability of public health SCs. Detailed discussions of the review can be found in Section 3.8.3.2 on survey assessment. The most suitable tool is the Global Health Supply Chain Maturity Model (GHSCMM) (Association for Supply Chain Management, 2020). Although the survey instrument was adopted, a pilot study was conducted to establish the reliability and validity of the scale, because this is the first study to use the GHSCMM instrument. The survey questionnaire was tested for reliability using test-retest and content validity in a pilot study (Polit and Beck, 2006). Six experts from the fields of supply chain management, healthcare, and academia who met a minimum of three of the five criteria (Appendix VI) were selected from the ten experts invited to assess the items from the questionnaire, and the scores were collated and used to calculate the item and scale Content Validity Index (CVI) using Microsoft Excel 2021. The five inclusion criteria comprised experts working in the field of SCM, healthcare SC organisation, academia teaching SCM, understanding of SC operations, and revolving fund procedures. The two exclusion criteria were having less than 3 years of experience and refusal to provide consent. The response rate was 60% met the criteria, 10% did not meet the criteria, and 30% did not show up for the survey. The output from the content validity assessment was good for items ranging from 0.83 to 1.00 and scale index using scale CVI/Average of 0.99. The scale CVI based on Universal agreement (UA) was calculated to obtain an S-CVI/UA of 0.93. The 67 questions excluded the first section of the assessment profile (Appendix IV). All 67 items were accepted, as the scores were above the minimum of 0.80. The questionnaire was pretested with the operators of the maternal and child SC at two different time intervals and was found to be reliable, as the output from the measurement showed 50-75% essential medicine stockout. This instrument was adopted to assess performance and medicine availability in the main study.

3.8 Case study data collection

The main case study data collection involves the selection of five (5) public healthcare SCs operating the essential medicine revolving fund in Kaduna State based on replication logic using the developed criteria. The selection criteria included SCs that had operated a DRF program for more than three years in Kaduna State. Case A met the inclusion criteria, and the selection of Cases B, C, D, and E followed replication logic (Yin, 2015) to identify cases that shared similar inclusion criteria with Case A. Evidence was collated using data sources, such as questionnaires, interviews, direct participants' observations during the group survey, and documentation. The interpretation of the results was based on a case-by-case study and triangulation of the data collected. This study used a maturity model tool to measure the performance of SCs to identify constraints and baseline performance. Stakeholders across SCs were interviewed using a semi-structured questionnaire for in-depth interviews. The interviews were recorded and transcribed using the Otter software. Systems thinking and dynamic methodology of quotation analysis is used to draw mental models of stakeholders in the healthcare supply chain and clarify the structure and dynamic feedback in the DRF SCs. Mental models of participants from the case study sites were combined and pruned to obtain a network model. The network mental model provides a clear understanding of the perception of system actors regarding how the system operates to make medicines available. The stock and flow model was drawn based on Sterman's distribution model (Sterman, 2000), and the model was simulated for policies aimed at reducing stockouts and increasing MFR. This study proposes a framework for the integration of public health SCs and links them to the performance of MFR at the SC network level.

This research utilised qualitative and quantitative methods to explore how SCI across organisations leads to SCP, as well as exploring the enablers and barriers of integration in healthcare SCs. The strengths of quantitative research are bias avoidance and the ability to replicate findings because of statistical analysis and interpretation, while the qualitative approach enables the exploration of complex situations (Creswell and Poth, 2016). Although qualitative methodologies are criticised as a possible source of researcher bias, the researcher can understand the social context and reasons behind the participants' responses. Similarly, quantitative research is criticised for providing only an overview of causal relationships among factors related to the situation (Creswell, 2009), which can avoid bias and ensure the replicability of the study. Learning how organisations integrate SCs in a socially constructed and complex world makes qualitative research appropriate for this study. Similarly, measuring the performance for continuous improvement and model simulation for optimum performance across networks makes quantitative methodologies equally appropriate for this study. Qualitative research enables researchers to understand how and why organisations integrating SCs can impact the provision of medicines. It enables an exploration of the people, structure, technology, and external environment of organisations and how this impacts performance. Quantitative research enables the measurement, modelling, and simulation of an integrated SC for improved performance. Although each research method has advantages and disadvantages when used individually, combining the two methods provides strong evidence for generalising the output from the study.

3.8.1 Case study system descriptions

The first case is the Kaduna State Health Supplies Management Agency (Case A) is the supply chain organization of the Kaduna State Government responsible for procuring, warehousing, Inventory management and data management of health products for distribution to 1088 hospitals in the State. The Agency procures and distributes medicines to hospitals across primary (1057), secondary (30), and tertiary (1) healthcare levels. Primary HF provides care for the prevention, rehabilitation, and cure of diseases at the LGA, while secondary HF operates inpatient, outpatient, and specialised services to patients. Tertiary hospitals provide specialised care for specific disease conditions. Patients are referred from primary to secondary and tertiary care levels depending on the severity of the condition (World Health Organization, 2017). The Agency handles products for malaria, family planning, non-tropical diseases, maternal, newborn, and child healthcare, essential medicines, tuberculosis, human immunodeficiency syndrome (HIV), and nutrition. The EMs supply chain is fragmented into a revolving drug fund and free maternal and child health products. This study focuses on revolving fund EMs supply chains. The second case was the National Ear Care Centre (Case B), a tertiary teaching hospital that trains specialists in ear, nose, and throat diseases. The hospital is located in the Kaduna North local government area of the state. Training of pharmacists, nurses, medical information officers, and audiologists was also carried out in the hospital. The hospital operates a drug revolving fund for EMs.

The third organisation is Ahmadu Bello University Teaching Hospital (Case C), a tertiary hospital in Zaria, Kaduna State. It is a referral teaching hospital with specialist professors in medicine, paediatrics, obstetrics and gynaecology, and other subspecialties of medicine and surgery. As a teaching hospital, it trains doctors, pharmacists, nurses, laboratory technologists, and other healthcare practitioners. The pharmacy department is responsible for providing medicine to patients in hospitals. The fourth case is the Federal Neuro Psychiatric Hospital (Case D) is a tertiary teaching that trains healthcare psychiatric healthcare practitioners. The hospital is in the Kaduna South local government of Kaduna State and operates the drug revolving fund for EMs from the pharmacy department. Finally, the National Eye Centre (Case E) is a tertiary teaching hospital located in the Kaduna South local government of the Kaduna State. The hospital trains ophthalmologists and other specialists. The pharmacy department operates the drug revolving fund for EMs in the hospital, in collaboration with other departments. All five case study sites operated revolving drug funds for essential medicines (Table 3.5). Essential medicine SCs have fragmented procurement, demand and supply planning, inventory management, and, in some cases, even warehousing is not integrated. Medicine procurement is directly from manufacturers, distributors, and retailers for all SCs.

Table 3.5: System Descriptions of Revolving Fund Essential Medicines Supply Chains and Delivery Channels

Case Study	Target level of care	Public healthcare focus	Ownership Structure	Delivery channels	Location in Kaduna
Case Study A	Medicine supply for Primary, Secondary, and Tertiary care	Supply chain organization	State Government	Primary Healthcare clinics (1057), Secondary healthcare hospitals (30) and Tertiary healthcare hospital (1)	Kaduna South LGA
Case Study B	Medicines supply for tertiary care	Specialist hospital	Federal Government	Active stores (3)	Kaduna North LGA
Case Study C	Medicines supply for tertiary care	Teaching hospital	Federal Government	Outstation pharmacy (3), Active stores (2)	Zaria LGA
Case Study D	Medicines supply for tertiary care	Specialist hospital	Federal Government	Active stores (8)	Kaduna South LGA
Case Study E	Medicines supply for tertiary care	Specialist hospital	Federal Government	Active stores (2)	Igabi LGA

Source: Abdulkadir *et al.* (2023)

3.8.2 Qualitative data collection methods

3.8.2.1 Key informant interviews

Ethical approval was obtained from the Liverpool John Moores University before the initiation of data collection. Semi-structured interviews were conducted to allow the researcher to probe interviewees to explain their responses. The interview protocol was developed based on the SC operational processes for obtaining medicines from the hospitals (Appendix II). Five key informants from five organisations were selected based on criterion sampling (Table 3.6). The responses provide an understanding of the levels of integration and medicine availability by analysing the DRF medicine acquisition processes. The interviews lasted 30-45 min. The interviews were recorded through notetaking and transcribed. Transcriptions were analysed using thematic analysis. Six themes on demand and supply planning, coordination, visibility, inventory management technology, teamwork, and patient trust were identified as critical to SCI processes to improve MFR.

Table 3.6: Criteria for inclusion and exclusion in key informant interview

Inclusion Criteria	**Exclusion Criteria**
Essential medicine Supply chain manager	Less than 3-years' experience in DRF program
Leads the operations of the DRF program	Refusal to give consent
Have complete understanding of the functional supply chain operations	
Full time staff of the institution	
Oversees the operations team responsible for providing essential medicines in the organisation	

3.8.2.2 In-depth interviews

Interviews were conducted based on the criteria developed for the five case study sites (Table 3.7). The interview protocol was designed based on the output of the key informant interviews. The questions were expanded and tailored to evoke causal statements of participants' mental models (Appendix V). The participants included internal stakeholders from the departments of pharmacy, accounts, admin, stores, procurement managers, manufacturers, distributors, donors, and third-party logistics providers making up the system element.

Table 3.7: Criteria for inclusion and exclusion of participants for case study in-depth interviews

Inclusion Criteria	Exclusion Criteria
Member of the DRF program	Less than 3-year experience in operations of the essential medicines revolving fund program
Suppliers of medicines and services to DRF program	Refusal to give consent
Partners supporting the DRF program	
Have complete understanding of the functional supply chain operations	
Full time staff of parent institution	
Contributes to the essential medicines supply chain operations	

Face-to-face, telephone, and virtual interviews were conducted with the 46 participants (Table 3.8). All interviews were recorded and transcribed using Otter software. Conversation fillers, repeated words, and phrases were removed from the interview transcripts. Open-text quotation analysis was used to interpret and analyse the transcripts from the interviews of each SC case study. This study designed an in-depth interview protocol based on grounded theory to explore the SCI processes (Charmaz, 2001). Within-case analysis was carried out to understand individual cases, and cross-case analysis to harvest and compare findings across cases (Eisenhardt, 1989).

Table 3.8: Number of participants for in-depth interviews across Cases A, B, C, D, and E

Participants' Department	Case A	Case B	Case C	Case D	Case E	Total
Pharmacy	1	1	2	2	3	9
Supply chain management	2	0	0	0	0	2
Administration & Planning	2	1	0	0	2	5
Accountant	0	1	1	1	2	5
Store	1	1	2	0	1	5
Procurement	1	1	1	2	1	6
Quality control	0	1	0	0	0	1
Manufacturer	2	3	0	1	1	7
Distributor	0	0	0	1	2	3
Third party logistic provider	1	0	0	0	0	1
Donor/partner	1	0	0	0	0	1
Nurse	0	1	0	0	0	1
Total	11	10	6	7	12	46

Source: Adapted from Abdulkadir *et al.* (2023)

3.8.2.3 Physical observation

Observational evidence was used to support the evidence from interviews by observing the environment of the five focal organisations and documented through field notes, photos, observation of warehouses, and meeting rooms. Field observations showed that there was a lot of disagreement within teams in answering the questionnaire, suggesting a lack of an established process for operations. Some teams and members were defensive at the onset of the exercise, while others became more relaxed after the team lead explained that the purpose of the exercise was to help the team work better and not to find faults. The members were encouraged to share their thoughts freely. The findings were anonymised to protect the participants' identities. Immediately after the group surveys, some members of the case study teams wanted immediate solutions to problems identified during the survey sessions. The outcomes of the survey sessions are discussed for each group.

3.8.3 Quantitative data collection methods

3.8.3.1 Prescription review

The Kaduna State essential medicines list, 2017 edition (Kaduna State Ministry of Health, 2017), which was derived from the National Essential Medicines List, was used to select seven classes of essential medicines to determine their consumption rate as the demand data. The classes of medications were anticonvulsant, anti-infective, antimalarial, antibacterial, analgesics, preparations for correcting water, electrolyte and acid imbalance, vitamins, and minerals (Appendix III). Thirteen (13) essential medicines were purposively identified under the seven classes of medicines as frequently used for the treatment of diseases. Key informants from the five facility case studies were asked to determine the demand for medicines in their organisations for the initial scoping. Key informants were then asked to identify the medicines with the highest consumption rates in their organisations. The source of the information was also required, either from prescription reviews, clinical case reviews, procurement data, or any other sources. Medicines with very high to moderate demand were identified through prescription and procurement data reviews of the five case study organisations. Of the seven classes of essential medicines, only three with very high to moderate demand were selected across the cases (Table 3.9). Consumption data and trends for the three moderate-to-high consumption medications were determined from January to December 2020 and used to validate the developed model. Sixty percent of the cases used prescription data to identify consumption trends, while 40% used procurement data.

Table 3.9: Consumption rate of selected essential medicine in cases A, B, C, D, and E

Class of medicines	Generic name of medicine (s)	Consumption rate (Moderate/Very High)				
		Case A	**Case B**	**Case C**	**Case D**	**Case E**
Anti-infective	Metronidazole	Very high	Moderate	Very high	Moderate	Moderate
Antimalarial	Artemether + Lumefantrine	Very high	Very high	Very high	Very high	Very high
Analgesics	Paracetamol	Very high	Moderate	Very high	Very high	Moderate
Source of evidence		Prescription review	Procurement data	Procurement data	Prescription review	Prescription review

3.8.3.2 Survey assessment

Several tools were considered for this assessment to select the most suitable tool for measuring the baseline performance. First, the national supply chain assessment tool is unsuitable for measuring end-to-end operational activities. The scores generated after the measurements did not reflect the total score. Second, the supply chain maturity scorecard can only be implemented manually using paper or Excel sheets, and the measures are not linked to performance outcomes. Collation of the results is burdensome with the use of paper. Third, the maturity model and deep-dive assessment tool require a good source of national records, and the period of assessment is over three months (United Nations International Children's Emergency Fund, 2019). Fourth, the SCOR model is an industry standard for measuring and improving SCM performance. Although it provides a comprehensive framework for measuring performance and benchmarking, it is cumbersome with lengthy periods and enormous resources required for implementation. Additionally, it is not suitable for complex healthcare supply chains with broad scope and poor data sources (Guhathakurta, 2022). Finally, the GHSCMM was derived from the SCOR model and designed specifically for healthcare SCs. Unlike generic SCOR models, which are unsuitable for measuring public healthcare supply chains with incomplete data sources, online GHSCMM is fast and easy to implement, with an immediate view of cumulative results (Association for Supply Chain Management, 2020). The GHSCMM tool can also be deployed without contact which makes it suitable for the coronavirus pandemic period owing to the requirement for minimal or no contact. Considering the time constraints, the number of cases, and the period of data collection which started at the beginning of coronavirus pandemic, the GHSCMM tool was the most suitable for measuring baseline performance in this study. Hence, the GHSCMM tool was adopted in this study to assess the five case study SCs.

The survey assessment was conducted using the online Global Health Supply Chain Maturity Model (GHSCMM) version 8.0 (Association for Supply Chain Management, 2020). The GHSCMM tool contains seventy-two questions which covers the strategic, operational, and tactical aspects of the SC (Appendix IV). This tool was used to measure the baseline medicine availability performance of Cases A, B, C, D, and E supply chains and the status of operational activities within the SC. A pilot study was conducted to test for reliability using the test-retest and content validity of the GHSCMM tool (Polit and Beck, 2006). A pilot study was conducted to establish the reliability and validity of the scale, as this research appears to be the first study to use the GHSCMM instrument from the literature review. The participants were purposively selected based on being subject matter experts in the supply and provision of medicines within the case study organisations. The gatekeeper was requested to identify and initially approach the potential participants on behalf of the investigator. A four-hour survey workshop was conducted from March to May 2021 (Table 3.10) for each case study organisation.

Table 3.10: Dates for group survey workshop in five study sites

No	Case Site for Maturity Model Session	Date conducted
1	Kaduna State Health Supplies Management Agency	23rd March 2021
2	National Ear Care Centre	25th March 2021
3	Ahmadu Bello University Teaching Hospital	31st March 2021
4	Federal Neuro- Psychiatric Hospital	28th April 2021
5	National Eye Centre	25th May 2021

Seventy-eight (78) respondents were selected purposively based on the developed criteria (Table 3.11) of being subject matter experts in the provision of medicines within case study organisations. The respondents represent the core team responsible for sourcing, storage, and customer order fulfilment of essential medicines within the organisation.

Table 3.11: Criteria for inclusion and exclusion of case study organisation

Inclusion Criteria	Exclusion Criteria
Public healthcare organisation	Less than 3-year experience in operations of the essential medicines revolving fund program
Operates the essential medicines revolving fund program	Refusal to give consent
Located in Kaduna State	
Owned by the Kaduna State government	
Owned by the Federal Government of Nigeria	
Responsible for the essential medicines supply chain operations	

Case A had fifteen (15) respondents, B (9), C (19), D (20), and E (15), as shown in Table 3.12. Case A was evaluated in a virtual workshop using Zoom software, while Cases B, C, D, and E were physically assessed in the respective organisations (Abdulkadir *et al.,* 2023). The coronavirus pandemic protocols strictly adhered to the use of personal protective equipment and physical distancing. Data were electronically computed and analysed for submission through the assessment portal. The results were viewed and discussed by respondents.

Table 3.12: Number of participants for performance survey assessment across Cases A, B, C, D, and E

Participants' Department	Case A	Case B	Case C	Case D	Case E	Total
Pharmacy	0	2	15	14	7	38
Supply chain management	9	0	0	0	0	9
Administration & Planning	4	2	0	0	2	8
Accountant	1	1	1	1	2	6
Store	0	2	1	1	3	7
Procurement	1	1	0	1	1	4
Quality control	0	0	2	0	0	2
Audit	0	1	0	1	0	2
Laboratory	0	0	0	1	0	1
Maintenance	0	0	0	1	0	1
Total	15	9	19	20	15	78

Source: Abdulkadir *et al.* (2023)

3.9 Triangulation of data

The evidence was collected from focal companies, external suppliers, customers, and stakeholders. Stakeholders such as the government and donors provide the seed stock or funding of essential medicine SCs, which receive funds from the government to implement the DRF program. Policies for improvement will also be designed and implemented in collaboration with the system operators. Hence, it is critical to obtain stakeholders' perceptions regarding the operations of the revolving fund and strategies for improving MFR. Information collected from suppliers, customers, and stakeholders was used to validate evidence from the focal companies. This increased internal validity through accurate analysis and inference of events across the supply chain. Triangulation was achieved by collecting evidence from more than one source, several informants within each case and across the supply chain (Abushaikha, 2014).

3.10 Conclusion

The philosophical underpinning of this research is based on relativism ontology and pragmatist epistemology to gain more understanding from the perspectives of suppliers, hospitals, patients, the government, and donors in the healthcare SC. A mixed method was used to collect data quantitatively and qualitatively from a multiple case study design of healthcare SCs. System dynamics methods were used to analyse and interpret data collected from five case study healthcare SCs.

4 CASE STUDIES AND MEASURING PERFORMANCE

4.1 Introduction

This chapter details the case study medicine availability performance measurement from the Global Health Supply Chain Maturity Model (GHSCMM) survey assessment. The assessment measured the medicine availability performance of the five supply chains as a prelude to in-depth interviews. The findings from the survey and interviews with DRF program managers were published in a peer-reviewed journal as preliminary findings from this research (Abdulkadir *et al.,* 2023). This section adopts measuring as one of the first stages of SD modelling (Pruyt, 2006), see figure 3.3 in Section 3.5. This chapter begins by outlining the case-by-case output of the performance measurement exercise followed by cross-case comparisons across cases. A case-by-case analysis precedes comparisons across cases to build robust evidence and generalise the findings. The chapter concludes with the findings from the assessment which were used to develop an interview protocol for the next phase of in-depth interviews.

4.2 Case study performance measurement

To assess the performance of integrated SCs, it is essential to measure the baseline performance of each case to gain insights into the SC operational processes and the challenges affecting SCs leading to medicine stockouts.

4.2.1 Case A maturity model output

All the case study sites have never used the GHSCMM v8.0 to assess their supply chain except Case A, which had near real time digital visibility of inventory and consumption. The average score for Case A was 75 percent (Table 4.5). The lowest category and weakest link are infrastructure and assets (50 percent) for Case A. However, Case A has trouble in procurement of medicines from budget constraints. The HF uses consumption records from prescriptions as demand data to request replenishment and is regularly tracked. Replenishment is on an as-needed basis and can be completed in less than 14 days by prequalified suppliers. The costs of operations and running the DRF were tracked monthly against the funding commitments. The availability of EMs is 50–75%, and greater than 70 percent of the medicines are affordable, and patients experience some wait times before accessing their medicines. Digital information about medicines and programs is transmitted to the HF. The use of digital technology supports the segmentation of product categories which are reviewed quarterly to facilitate inventory planning from the warehouse to the

Service Delivery Points (SDPs). Although Case A had constant Internet access, only a few SDPs had the Internet, making their operations cumbersome. Access to the Internet made it easy for Case A to use a data-driven decision-making approach to decide when and where to ship medicines. The Visibility and Analytics Network (VAN) is available to all operations staff and is reviewed regularly during weekly sales and operations planning meetings. The use of data helps improve the performance of Case A SC. The delivery lead time is communicated to the SDPs so that they can prepare to receive products. Open orders were resolved using the WMS and viewed digitally. The WMS assists in order processing and delivery of lead time to SDPs within seven days. The expected shipments and deliveries are also visible and can be tracked. The HF orders are staged before shipment, and 80% of the orders are delivered completely to the HF on-time. Orders were selected and staged in preparation for shipment, and the inventory accuracy was greater than 97 percent. Quality assurance is used in all stages of warehouse operations such as receiving, staging, picking, stocking, and shipping. Essential medicines are kept dry and safe at all stages by security personnel to prevent pilferage and theft. Inventory management policies were used to develop the supply plan. Only authorised staff are allowed to enter warehouse premises. Case A uses a weekly scheduled delivery list to determine the product movement to the SDPs. Shipments are verified upon delivery by SDPs staff against the Proof of Delivery (POD) and returned to the warehouse. Case A used the First Expiry First Out (FEFO) policy and Standard Operating Procedures (SOPs) to prevent medicine expiries. First, medicines with shorter expiry dates were used. Active tracking of expiries and the use of SOPs to safely dispose expired medicines was conducted on a regular basis. Staff members actively tracked, documented, and pulled the expired product from storage and disposed of the expired product according to SOPs.

Case A prioritised capacity-building and engaging in continuous training and retraining. Supply chain certifications are encouraged and supported by management. The focus on training ensures that most staff members have basic and SC improvement skills to help them perform their duties seamlessly. Performance management was implemented using scorecards and dashboards to solve problems and ensure continuous improvement. The staff is empowered to review and act on 50-80 percent of the indicators. The roles and responsibilities of staff members were documented, and relationships were managed using the Responsible, Accountable, Consulted, and Informed (RACI) framework. Leadership and capacity development are deployed to ensure that all roles are staffed, and leaders support their teams to collaborate and work with stakeholders to achieve organisational goals. Analysis showed a total number of 73 counts for supply chain constraints in Case A.

Table 4.1: Survey assessment output across five healthcare supply chains

Supply chain categories	Case A percentage (%)	Case B percentage (%)	Case C percentage (%)	Case D percentage (%)	Case E percentage (%)
	Score Obtained				
Service-Delivery Point (SDP)/ HF Visibility	66.7	62.2	56.7	53.3	45.9
SDP/HF Inventory Management	90	80	75	72	66.7
SDP/HF Order Management	80	66.7	58.3	56	51.1
Warehouse/Store Visibility	86.7	77.8	70	65.3	56.3
Warehouse/Store Inventory Management	90	80	75	70	62.2
Warehouse/Store Order Management	80	75	62.5	54	41.7
Warehouse/Store Operations	93.3	91.1	73.3	64	47.4
Transportation	60	57.8	51.7	45.3	36.5
Expiry Management	90	73.3	70	60	46.7
Procurement	73.3	64.4	60	57.3	51.9
Infrastructure and Assets	50	50	52.5	46	37.8
Performance Management	80	66.7	60	53.3	41.5
Analysis and Evaluation	100	80	75	64	44.4
Demand Planning	70	70	67.5	58	42.2
Supply Planning	80	73.3	70	60	42.2

Fund Management	60	46.7	40	36	28.9
Financial Management	60	46.7	40	36	28.9
Governance	60	53.3	47.5	42	32.2
Staff Training/Development	70	53.3	50	44	33.3
Patient-Focused Performance	60	60	56.7	54.7	52.6
Average Score	75	66	61	55	45

Source: Abdulkadir *et al.* (2023)

4.2.2 Case B maturity model output

Case B never conducted maturity model assessment using GHSCMM v8.0. The visibility and consumption of medicines are digitally near real time. The average score for Case B was 66 percent. The constraints in Case B were found to be fund and financial management, with a score of 46.7 percent. Financial constraints lead to a budget deficit that can delay the sourcing and procurement processes. Information from manufacturers and suppliers is not readily available unless requested by the staff members. Information regarding essential medicines is shared manually, making it difficult for SC partners to obtain information. There is no categorisation of products at the warehouse, and staff members are not able to track medicine stockouts. The SC was manually operated, and a visual process was used to determine the reorder point. Owing to the size and arrangement of products, identification of medicines is easy for the manual pick-and-pack process. Case B reported that manual identification of order locations allowed access to information on medicine orders in transit. The frequency of medicine stockouts and reorders was used to replenish products in the warehouse. SDPs orders were processed and reviewed weekly with short delivery lead-times. Medicine orders are then picked, packed, staged, and shipped. Products that are unavailable are procured from vendors. The on-time full-delivery rate was less than 80%. Inventory accuracy has been reported to be 90–97 percent. Quality inspection takes place to keep the product safe and in good condition, with adequate security to prevent theft.

Weekly delivery is scheduled for SDPs orders. Although a delivery schedule is available, staff members can only access information upon request. After delivery, the medicines are verified for accuracy, and POD is returned to the warehouse for documentation. Handling expired products is carried out by staff members attempting to regularly identify expired products. The staff also actively tracked, documented, and pulled the expired product from the storage. The procurement of medicines is completed in less than one month. The SC uses consumption data to plan quarterly procurement and supply. Digital information sharing is not available, as SDPs lack access to the Internet. There is no proactive identification or management of SC bottlenecks. Problems are solved when they arise in the system. This could be related to the report of only a few staff members with little performance improvement skills, even with the support of managers encouraging solution brainstorming sessions. Most EMs operators lack essential supply chain knowledge, leading to difficulties in solving day-to-day operational problems. The SC tracks the demand plan on a monthly or quarterly basis, and uses it to create a supply plan. As the DRF budget is unknown, there is no financial visibility, and the procurement team cannot access funds for replenishment. Supply chain costs were neither measured nor tracked to further confound financial management. supply chain roles are not clearly assigned, leading to conflicts, even though the organisation is adequately staffed. There is access to medicines as more than 70% of EMs are affordable, but patients can be delayed in some cases. The supply chain constraints in Case B have a total of 90 counts (Table 4.2).

Table 4.2: Number of constraints across five healthcare supply chains

Category of constraints	Case A Count	Case B Count	Case C Count	Case D Count	Case E Count	Total Constraints Count
Human resources	5	10	12	19	19	65
Improvement-process knowledge	8	9	18	20	19	74
Enabling technologies	17	18	20	20	19	94
Leadership/guidance	4	3	20	0	1	28
National guidelines	0	1	6	1	2	10
Funding	18	19	20	20	19	96
Infrastructure	19	18	19	20	19	95
Government support	1	10	20	16	18	65
No public/private collaboration	0	2	0	0	1	3
Wait times at HF	1	0	0	0	0	1
Total Count	73	90	135	116	117	531

4.2.3 Case C maturity model output

Case C has never conducted a maturity model assessment using GHSCMM v8.0. The organisation only has monthly visibility of inventory and consumption. The average score for Case C was 61 percent. The lowest category was reported as funds and financial management, with a score of 40 percent. There is no information sharing from medicine suppliers, and the relationship is mainly transactional. Even when information about medicines is requested from suppliers, it is shared on paper or manually. EMs are handled together without segmentation, and the organisation only reacts to depleted inventory and stockouts. Monthly physical stock counts of medicines and health supplies were conducted to track product availability, and a visual process was used to determine the need to order more inventories. The difficulty of locating products using manual tools leads to expiries and stockouts. The shipping lead times were uncertain, as Case C could not provide the expected delivery dates to SDPs. Open orders are left unresolved and delivery schedules are not implemented, increasing the uncertainties in the system. The inventory accuracy was not measured or tracked. This means that shrinkage and theft cannot be detected in the warehouse. The organisation has no procedure for conducting standard quality checks, and the staff try to keep the products dry and safe from harsh weather conditions. There is no scheduled delivery of products to SDPs, and communication for locating product orders and shipments is lacking. When the SDPs receive orders, manual confirmation is conducted before returning the POD to the warehouse. Handling expired products is carried out by staff members attempting to regularly identify expired products.

Although the normal replenishment cycle was quarterly, Case C reported the ability to complete procurement in two weeks using existing supply and stockout counts for replenishment from prequalified suppliers. The Internet is a major challenge because only a few SDPs have access to it. Case C managed performance by identifying problems, as they occurred using a dedicated team to conduct random reviews and the analysis findings. Problem-solving skills are minimal, but some managers have the basic SC knowledge which they deploy in performance improvement. The previous year's demand plan was used to create plans for subsequent years and was tracked on a monthly or quarterly basis. The visibility of budget allocations is lacking and the release of funds for procurement is irregular. The costs of running the program were not tracked which could explain the SC's financial management constraints. While Case C had enough staff, the patients found it difficult to access EMs. Wait time to access medicines is lengthy which could complicate treatment or lead to loss of life at SDPs. More than 50% of medicines are stocked out, but 70 percent of the available medicines are affordable to patients. The supply chain constraints in Case C had a total of 135 counts. Case C had the highest constraint count (Table 4.2).

4.2.4 Case D maturity model output

Case D has never conducted a maturity model assessment using GHSCMM v8.0. The organisation only has monthly visibility of medicine inventory and consumption. The average

score for Case D was 55 percent. The lowest category, with a 36 percent score, was fund and financial management. Medicine suppliers do not share inventory information with Case D SC unless requested by the management. The information shared upon request is manually using paper, as digital tools are not available. There is no inventory segmentation, and the organisation only reacts to depleted inventory and stockouts. The physical stock count of medicines and health supplies was regular and conducted monthly. SDPs use manual or visual processes to determine the need to order more inventory for patient use. The manager authorised the amount of medicine to order. The arrangement of the warehouse eases the location of a particular product, and warehouse staff can only track orders but have no visibility of incoming and outgoing inventory. Case D had no method for defining an optimum inventory level. SDPs orders were difficult to process in the warehouse, and information on ship-date requests was not provided. Case D had no process for identifying and resolving open orders. The organisation does not track delivery, and SOPs for order fulfilment are not available. Quality problems were identified randomly without a defined process. There is no regular schedule for delivery to the SDPs. The warehouse had no process for verifying the receipt of products at the SDPs. There are no policies or processes in place to handle expired products. Procurement of medicines is completed in more than one (1) month and is carried out on a need's basis with no standard process to determine procurement quantity. Only a few SDP's had available Internet access. Case D had no process for identifying problems or opportunities. The staff had no problem-solving skills and did not carry out data analysis and evaluation. Staff lacked basic supply chain knowledge and had little or no experience with SC improvements, but managers encouraged teamwork during problem-solving. There is no demand or supply plan for planning purposes.
The budgetary allocation for SCM is unknown, and funds are not available for medicine procurement. SC costs are not tracked and staff members are not assigned clear roles. Top management roles were left unfilled and access to SC services was cumbersome for patients with extensive wait times. Medicine availability is reported to be 50 – 75%, with 30–50 percent of the available medicines identified to be expensive, leading to reduced access to patients. The supply chain constraints in Case D had a total number of 116 counts.

4.2.5 Case E maturity model output

Case E has never conducted a maturity model assessment using GHSCMM v8.0. Case E had only monthly visibility of inventory and consumption. The average score for Case E was 45%, which was below the average. A score of 28.9 percent was reported to be the lowest for Case E SC. information from suppliers is not shared with the warehouse and the SDPs. The request for information is shared through word-of-mouth and paper-based communication. All products are handled without categorisation and there is no mechanism to detect stockouts proactively. The physical stock count of medicines and health supplies was regular and conducted monthly. SDPs use manual or visual processes to determine the need to order more inventory for patient use. The manager authorises the amount to the order. The arrangement of the warehouse eases the location of a particular product, but warehouse staff cannot identify the inbound and outbound inventory. Inventory management strategies are not defined, making it difficult to manage order processing and provide the expected delivery dates. Case E had no process for identifying and resolving open orders, checking when medicines were delivered, or the quantity to ship. The warehouse staff randomly identified quality defects in the products. Last mile delivery is unscheduled, and there is no communication with SDPs regarding delivery. The warehouse had no process for verifying the receipt of products at the SDPs. There are no policies or processes in place to handle expired products. Procurement of medicines is completed in more than one (1) month and is carried out on a need's basis with no standard process to determine procurement quantity. Internet access was unavailable at the study site. Case E had no process for identifying problems or opportunities. The staff had no problem-solving skills and did not carry out data analysis and evaluation, but teamwork was encouraged during problem-solving. Inventory planning is performed without demand or a supply plan. The budget for the DRF is not defined, and the release of funds for procurement is unreliable. Understaffing the management cadre presents shortcomings in providing leadership to guide the achievement of SC goals. Medicine availability was shown to be 50 – 75%, and 30–50 percent of products were expensive and unaffordable to customers. The SC constraints were 117 counts for Case E.

4.4 Cross-case analysis

In summary, 80 percent of the cases did not measure their baseline performance with the GHSCMM tool, whereas 20 percent used the survey tool once for PM. Fund and financial management was the lowest category in four cases, including Cases B, C, D, and E. Asset and infrastructural deficits constituted the lowest category for Case A. SCs with financial management challenges also have difficulty determining their budgetary allocation for the DRF program due to lack of visibility in cash flows and the manual system of handling cash transactions. The lack of financial visibility hinders the sourcing and replenishment of essential medicines. The infrastructural challenges in Case A can be related to the lack of IT systems and Internet access at the SDPs which limit information flows across the SC. Investment in ICT equipment and unlimited access to the Internet at all locations will ensure smooth flows of information and EMs. Lack of infrastructure relates to funding constraints, and the focus must be on resolving the two for improved supply performance. Examining SC bottlenecks led to the identification of Case C with the highest constraints (135 counts). Case E had 117 counts, followed by Case D with 116 counts, and Case B had 90 counts of SC constraints. The lowest number of constraints was observed in Case A, with 73 counts (Table 4.2). The three categories constitute 54 percent of constraints across the SCs include government funding, SC infrastructure and technologies for inventory management and distribution of medicines. The patients' wait time category had the least constrained 1 count (Figure 4.1).

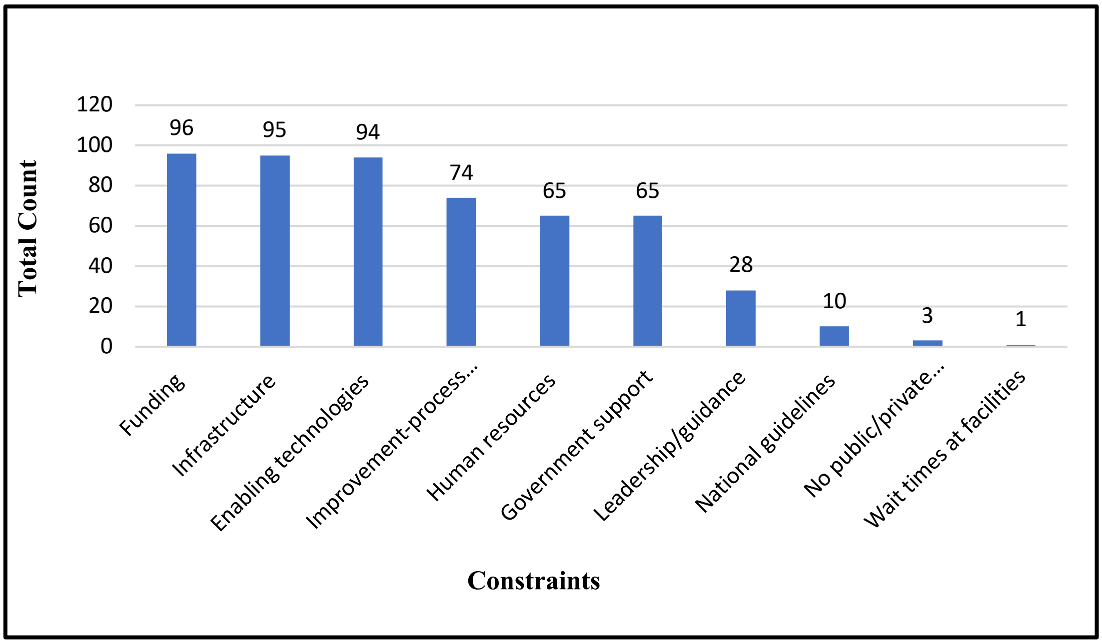


Figure 4.1: Total number of constraints across Cases A, B, C, D and E

The survey findings indicated that EMs stockouts are a challenge across all five SCs. Essential medicine stockouts with similar findings regarding manual information handling and unplanned demand and supply approaches have been reported in previous studies (Vledder *et al.,* 2019; Tang *et al.,* 2020). The use of consumption data from this assessment leads to EMs stockouts and a low MAP for patients which is in line with the findings of Leung *et al.* (2016), where failure to capture time delays and dynamic feedback from lead times led to stockouts. This could also be responsible for EMs stockouts from the survey assessment, as 80 percent of SCs do not measure or track their DRF performance. Innovative strategies to improve financing have failed to minimise stockouts, as observed by Sieleunou *et al.* (2020). This shows that a multifaceted approach must be deployed to understand EMs supply chains in order to improve availability. Cases B, C, D, and E had funding constraints, but efforts must be made to understand the dynamics of these constraints on the provision of medicines, as previous unidirectional approaches failed to resolve the problem of medicine stockouts. The number of prescriptions generated in public healthcare supply chains is enormous; hence, manual processes are prone to errors and failure to achieve the organisational objectives of saving lives. The maturity assessment showed that most supply chains did not have tools to measure their performance, except for Case A, which adopted a performance-driven approach to medicine supply. Healthcare workers are burdened by supply chain and patient management. Digital tools to prevent errors in dispensing medicines and to accelerate the process must be provided to increase staff productivity. Case A had digital platforms which could be responsible for the observed better performance compared with the other cases. Kumar *et al.*, (2017) and Oh *et al.* (2020) observed that technology platforms increase the speed and access to information in the supply network leading to higher performance which supports the findings from this study.

Integrated digital platforms aid SC managers in strategic and operational decisions. Digital technology improves data flows and enables the location and tracking of medicines against financial transactions. Case A managed and tracked operational costs, leading to increased visibility. This visibility helps with demand and supply plans, further reducing the EMs stockouts. Expanding IT investments to cover all SDPs in Case A increases product availability. Defining roles and responsibilities is critical for the smooth operations and ease of coordination in the system as demonstrated by Case A to enhance partner collaboration and project implementation as noted using RACI matrix in previous studies conducted by Costello (2012), Khan and Quraishi (2014), and Kozina and Sekovanic (2015). Unlike Cases B, C, D, and E, where few staff members had fundamental SC knowledge, Case A reported that most personnel had basic awareness of SCM and were encouraged by the management to go for advanced SC courses and certification. Having SC knowledge and skills is a prerequisite for successful order fulfilment and patient satisfaction (Wowak *et al.,* 2013; Chen *et al.,* 2023). The management of Cases B, C, D, and E should invest in supply chain learning and digital platforms to improve their performance. Case A can be used as a reference model for other SCs to share their knowledge and best practices. SCs must examine the roles and responsibilities of every team member to create alignment and boost the capacity to deliver medicines to patients.

4.5 Conclusion

Findings from the performance assessment show that all case study organisations experience medicine stockouts. The cross-case analysis indicates constraints leading to stockouts that include infrastructure and financial management challenges. The majority of SCs do not measure or manage their performance, making it difficult to assess the extent of stockouts and the damaging effects on disease management and patient satisfaction. Case A is a better-performing SC than the other cases. Other SCs can learn from Case A's experience in managing medicine availability to improve performance. The government needs to invest in IT infrastructure and SC capacity building for health sector SC. This section concludes with a cross-case output for the five SCs. The results from the assessment flow into the development of the protocol for in-depth interviews of individual participants in all cases are presented in the next chapter.

5 CASE STUDIES AND DYNAMIC FEEDBACK SYSTEMS

5.1 Introduction

This chapter outlines the results of in-depth interviews with participants, medicine manufacturers, distributors, third-party logistics providers, and donors. This chapter presents a quotation analysis (Tomoaia-Cotisel *et al.*, 2022) of all interviews and mental models of participants. Mental models explore the challenges behind integration leading to medicine stockouts and poor fill rates. A cross-case mental model dynamic hypothesis was developed to propose a theory of SCI that leads to improved medicine fill-rate performance. The dynamic hypothesis is a conceptual network model of SCI. A conceptual model was used to develop the simulation model in the next section.

5.2 Mental models of Interview quotation analysis

Forty-six interviews were conducted and analysed using quotation analysis across five case studies. The interviews cut across Internal Staff (IS) of the case study organisations from different departments involved in operating the revolving fund. The internal staff made up 74 percent of the interviewees (Table 5.1). External partners, such as Medicine Manufacturers (MM), Medicine Distributors (MD), Service Providers (SP), and one Donor (DN), were also interviewed to understand their perceptions of the DRF system and its effect on their operations in providing medicines for patients. External partners make up 26 percent of the participants.

Table 5.1: Category of participants across cases A, B, C, D, and E

Stakeholder category	Case A participants	Case B Participants	Case C Participant	Case D Participant	Case E Participant	Total (%)
Internal staff	7	7	6	5	9	74
External partners	4	3	0	2	3	26

The interview transcripts were divided into two groups to determine the saturation point of interpretation analysis (Francis *et al.*, 2010; Guest *et al.*, 2020). The first group was labelled the new variable group, while the second group was the variable saturation group. Four interviews were selected (Guest *et al.*, 2020) from each case as the new variable group, resulting in a total of 20 interviews across five cases. The remaining twenty-six interviews were assigned to the variable-saturation group. Only 15 cases were used to achieve saturation from the group two interviews (Table 5.2). The first group of interviews for each case was interpreted and analysed, followed by a saturation test using a test size of two interviews per run from the variable saturation group. The saturation point was set at zero percent to ensure that all variables were captured (Guest *et al.*, 2020) and no new variables were generated beyond the saturation point. The identified variables were used to draw words and arrow diagrams and then converted into causal loop diagrams depicting the mental models of the interviewees. The mental model from each case study was pruned and combined to develop a case-study mental model. Five case study models were combined and pruned (Kim and Andersen, 2012; Turner *et al.*, 2013; Tomoaia-Cotisel, 2018) to develop a mental network model for healthcare SCs. The network model is the proposed dynamic hypothesis of SCI, which leads to MFR performance. The dynamic hypothesis as defined by Lane (2000) is "the idea that a certain causal structure explains a certain dynamic behaviour". This dynamic behaviour corresponds to MFR performance.

Table 5.2: Interview groups for identifying new variables and saturation point for Cases A, B, C, D, and E

Interview analysis group	Case A Participant	Case B participant	Case C Participant	Case D Participant	Case E Participant	Total
New variables interview	IS01 IS03 SP43 MM45	IS05 IS07 IS22 MM47	IS02 IS11 IS20 IS21	IS04 IS08 MD40 MM39	IS09 IS23 IS24 IS25	20
Variable saturation interviews	IS06 IS15 DN62 IS31	IS38 IS36	IS17 IS19 MM42	IS10 IS16 IS34	IS26 MM54 IS29	15
Total	8	6	7	7	7	

Key

Internal Staff (IS)

Medicine Manufacturers (MM),

Medicine Distributors (MD)

Service Providers (SP)

Donor (DN)

5.2.1 Interpretation of medicine availability feedback mechanisms

The availability of medicines in SCs depends on the sale of medicines and replenishment of depleted stock. The CLD shown in figure 5.1 depicts the reinforcing and balancing feedback loops that determine availability and stockout.

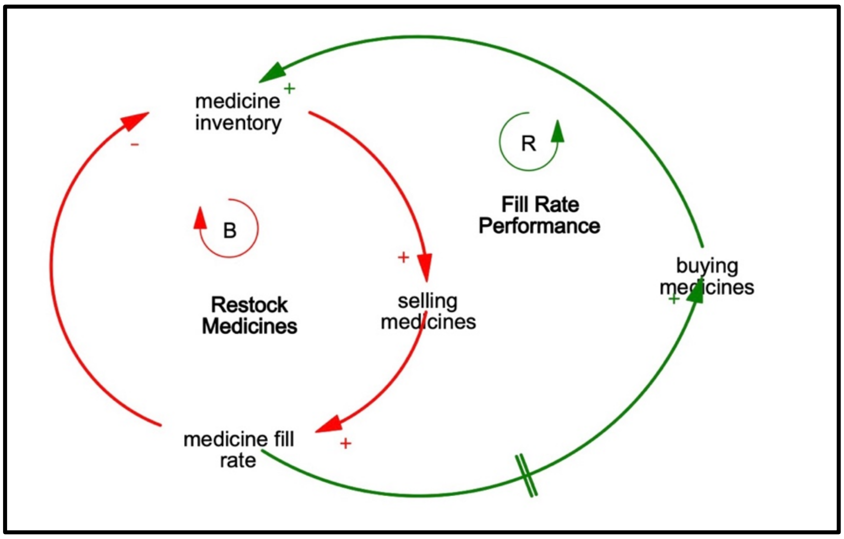
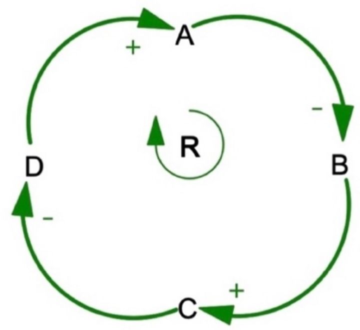
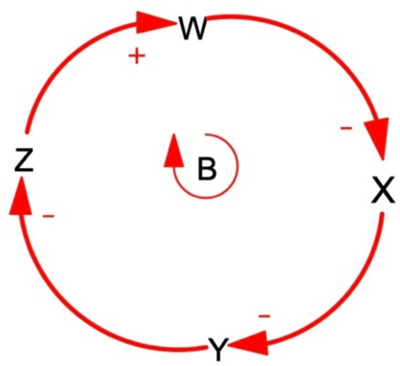


Figure 5.1: Medicine availability causal loop diagram

The polarity of the causal loop diagrams with a **(+)** sign indicates the same direction and **(−)** indicates the opposite direction (Table 5.3).

Table 5.3: Description of feedback loops and interpretation

Types of feedback loops	Polarity of feedback loops	Interpretation of loops
Reinforcing loop		When A increases, B decreases B decreases, C decreases C decreases, D increases D increases, A increases
Balancing loop		When W increases, X decreases X decreases, Y increases Y increases, Z decreases Z decreases, W decreases

5.2.2 Case A mental model of medicine availability

Case A had three reinforcing loops and three balancing loops (Figure 5.2). The SC is struggling with collaboration and process integration, as stated by an internal staff IS01:

"…The teams will have to first understand that they need each other to be successful, it's not a competition. …it needs to be an integration and a collaboration within the team. Then secondly based on how the operation of that organisation flow, …will have to look at their process and pinpoint the best way to communicate, communication is key, so if they are good in technology, that'll be fine". (Abdulkadir *et al.,* 2023)

Enabling communication between medicine delivery processes and technology improves visibility and fill rate. Sharing information with medicine suppliers aids network integration and customer satisfaction, as patients receive their medicines on time. Staff digital capacity to use technology is a requirement for reducing time delays in sharing demand data. The above statement shows that there is a need to develop digital SC skills to enable process integration with suppliers and to build trust. Beyond adopting technology, a cultural shift in the use of technology for information sharing with all stakeholders enhances data-driven decision-making in SCs and boosts medicine production. Integrating production and hospital procurement reduces stockouts and improves customer satisfaction. Delays in building trust lead to transactional relationships between suppliers and stockouts of essential medicines. Communication delays could also be responsible for donor/partners working independently, as they hinder effective collaboration and prevent access to funding from the government. Transparency in pricing increases access to medicines and builds trust in customers. Late payment by hospitals for medicines procured from suppliers leads to delays in the delivery of more medicines, even when they make efforts to pay later, as stated by the manufacturer MM45:

"once the <u>orders are collected</u>, the commercial department … the first thing they will do is to … <u>check the credit status</u> of … the customer. … they look at the <u>customer receivable</u> to understand whether the account is aged or not aged. …whether the account has <u>exceeded its credit limit,</u> if the account … is within the normal credit limits days …not gone beyond ninety days. … the account will be okayed to be approved for the next stage".

Apart from late payments, a lack of access to medicine demand trends from hospitals prevents adequate planning for production and distribution. Manufacturers also send their reorder levels to raw material suppliers. Hospitals do not understand that the raw materials needed for production rely on demand information from hospitals and the extent to which manufacturers also work with their suppliers with information from hospitals to make medicines available. Unavailable data for demand planning from hospitals lead to medicine stockouts from manufacturers which cascade throughout the network. Unlike hospitals, manufacturers' performance management of medicine volume and revenue budget targets determine the delivery of medicines to hospitals. On the other hand, the hospitals continue to buy medicines more than they need because of stockout anxiety leading to shrinkage from expiries.

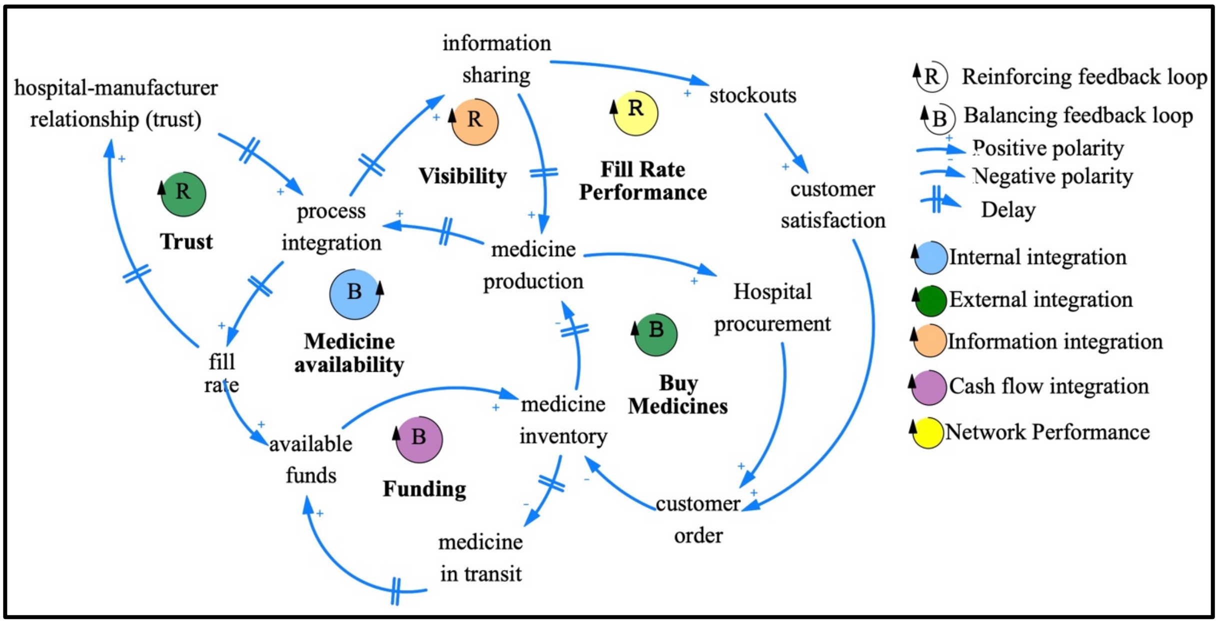


Figure 5.2: Integrated supply chain mental model for Case A participants

5.2.2.1 Causal interpretation and analysis of quotations in Case A

IS01-12 statement has a reinforcing performance loop and balancing price loop (Figure 5.3). The continuous availability and flow of medicines leads to a decrease in price which reinforces more selling and decreases the medicine inventory. Affordable medicine prices increase customer orders and decrease the on-shelf medicine inventory. The IS03-13 statement below noted the importance of measuring patient wait time, as increasing stockouts lead to long wait times and decreased fill rates and financial performance.

"… we measure how long it takes to serve a customer, so we've been able to set service level whereby we examine stock of all our customers in all the facilities every 20 days, such that within the 20 days we're able to look at the stock and measure and give them products when they're close to being stocked out. Twenty-five days products are given to the facilities based on their consumption. And then, beyond the twenty days, the dashboard begins to turn red to indicate that we haven't been able to meet that service level. we also measure the order fill rate. So, if an order is generated by our system, how much of this order are we able to fill, up to 90% or 70% So, our performance is measured by how much order we are able to fill. … they may be more in terms of budget performance, …we have set budget in a year to do certain activities, how much of those activities, have we been able to execute …". (IS03-13)

Even though IS03 states the organisations efforts at measuring internal performance, concerns are raised on the need to "bring in our customers, stakeholders' perspective into this" for the team to "improve our lapses, and then know our performance from both external and internal function within the organisation". This statement shows that it is important to view and measure performance from the stakeholder and customer perspectives to improve network performance. The success of network partner collaboration rests on improving "our level of transparency" and not "showing off what you are doing" but rather "where the lapse is". Transparency should be extended to other partners like the civil society organisations to get feedbacks "voice out the feelings of customers or patients". These statements show that full transparency to show where the process is working and where there is a need for improvement is a prerequisite for trust between all partners. On the other hand, the medicine manufacturer MM45-01 states that when a hospital has "exceeded its credit limit", it means "the customer cannot buy more". From the suppliers' perspective, sending more orders for replenishment does not guarantee order fulfilment when the credit limit is exceeded.

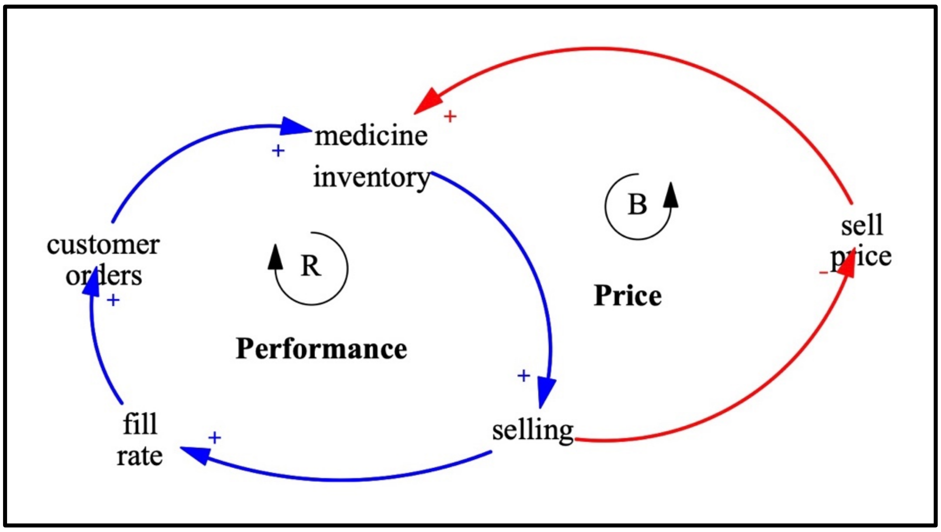


Figure 5.3: Performance and price loops leading to stockout in Case A

The logistics service provider SP43-04 mentions the detection of "aberrations in quantities and supplies" and the ability to sense and respond "early warning signals" to quantity changes from forecast is critical to increasing MFR. Although teams engage in forecasting and quantification, the use of early warning signals prevents errors and improves performance. Staff rely heavily on feedback and visibility to serve customers and consider digital technology as the backbone of running operations successfully. Hence, reducing time delays with automation minimises supply delays and ensures that hospitals get medicines on time. Delivery errors are detected from the performance feedback in the system and are used to improve customer satisfaction. A communication plan for all stakeholders is critical to ensure on-shelf availability of medicines. Designing a communication plan that aligns with stakeholder needs will improve stakeholder satisfaction. Analysing the causes of stockouts across variables in Case A shows some similarities to internal staff (IS) and medicine manufacturers (MM) in trust, visibility, and information sharing. Differences in internal staff perceptions (IS01 and IS03) of process integration as important to preventing stockout are not reflected by service providers and manufacturers (SP43 and MM45) as shown in Table 5.4. Only one manufacturer (MM45) agreed with IS01 regarding the effect of medicine production on stockouts.

Table 5.4: Analysis of variables leading to medicine stockout within Case A

Variables causing stockout in Case A	**IS01**	**SP43**	**MM45**	**IS03**
Hospital-supplier relationship (trust)	√	√	√	√
Visibility	√	√	√	√
Information sharing	√	√	√	√
Medicine production	√	-	√	-
Fill rate	√	√	-	√
Procurement	-	√	√	√
Process integration	√	-	-	√
Medicine in transit	√	-	-	-
Customer satisfaction	-	√		√

Evidence of the effect of sell price feedback on increasing medicine availability and network performance in Case A is shown in Table 5.5. See Case A interview analysis in Appendix IX.

Table 5.5: Evidence for increasing medicine availability and network performance

ParticipantNumber-Quote number) "... variables in Phrase(s)" (word count in variables/total word count in causal statement)	**Phrase(s) from participant quote denoting model variables**	**Interpreted model variables**	**Causal link between model variables (→=causal link, --||→=causal link with delay, +/- =positive or negative polarity)**	**Themes from participant quotes**
IS01-12) "Yes, because it means that the organization is achieving its goals …and it's an incentive for the organisations to do better. There is increased demand and on-shelf availability of products which will lead to higher turnover for the drug revolving fund even though it is a government organisation … is not for profit. However, it will reduce out of pocket expenses for the patients." (64/66)	-incentive for the organisations to do better - increased demand - on-shelf availability - which will lead - turnover - out of pocket expenses	Fill rate Customer orders Medicine inventory Time delay Selling Sell price	Fill rate→+Customer orders→+ Medicine inventory--//→+ Selling Selling→-Sell price→+Medicine inventory	Network performance IS01 believes that increasing fill rate will lead to decreasing sell price over time.

Source: Adapted from Abdulkadir *et al.* (2023)

5.2.2.2 Case A conceptual model saturation

The new variable group of interviews for Case A quotation interpretation was MM45, IS01, SP43, and IS03, whereas the validation saturation group included IS06, IS15, and DN62. The cumulative variables for each participant were identified and recorded for group one and rearranged in ascending order. From the second group of interviews, IS06 was analysed, and variables were compared to the first group to identify new variables. Three new variables were identified and the cumulative values were plotted on a graph (Figure 5.4). IS15 and DN62 had zero percent variables with saturation points before IS15. The same saturation analysis was conducted for the causal links, causal loops, and time delays. The causal link and causal loop saturation point were before the IS15 interview analysis (Figure 5.5 and figure 5.6). The time delay saturation point was before the DN62 interview analysis (Figure 5.7).

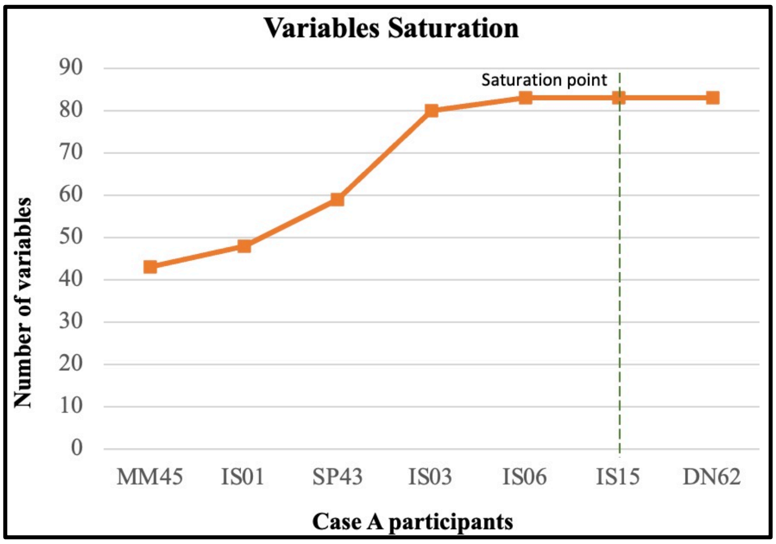


Figure 5.4: Case A conceptual model variable saturation

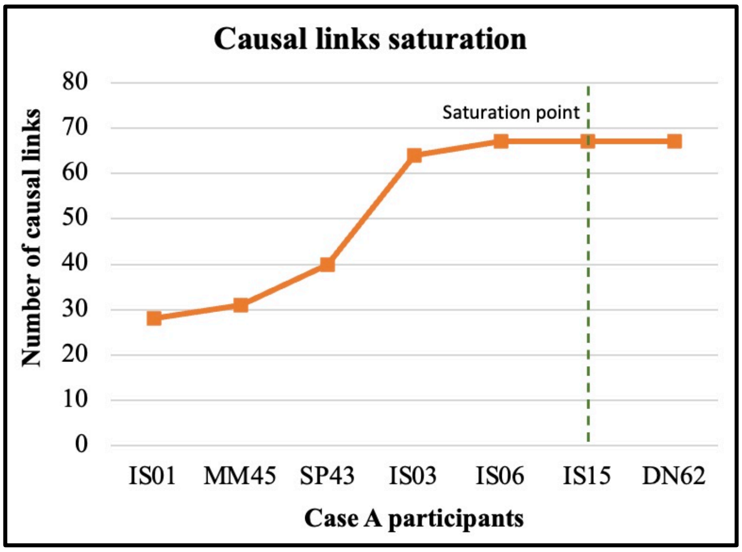


Figure 5.5: Case A conceptual model causal links saturation

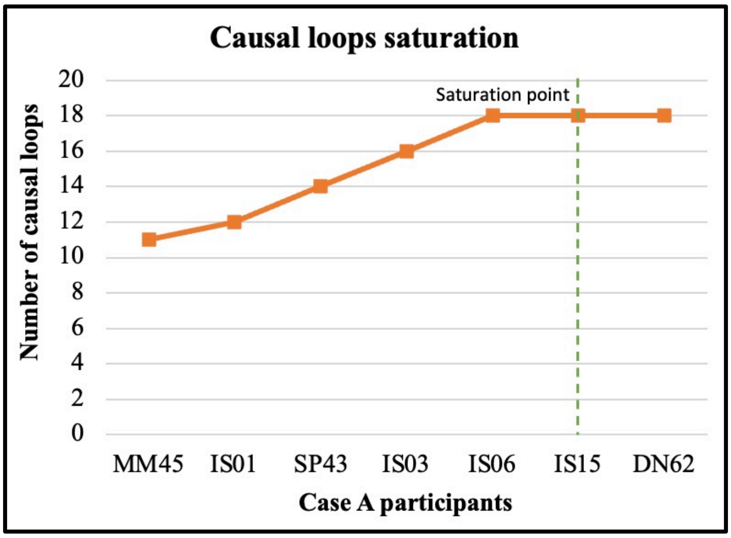


Figure 5.6: Case A conceptual model causal loops saturation

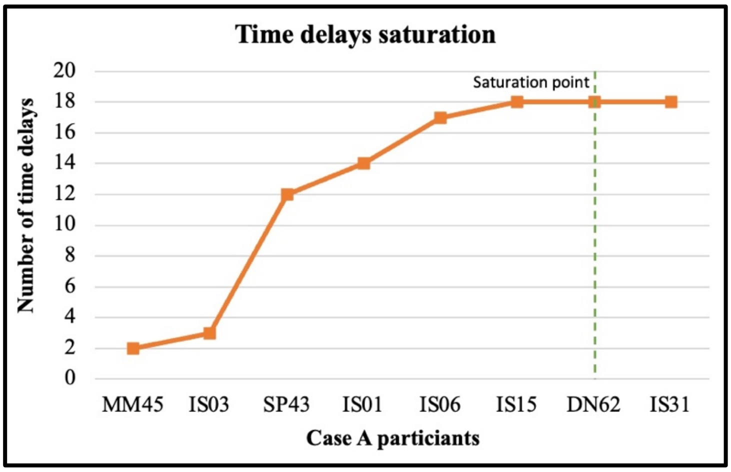


Figure 5.7: Case A conceptual model time delays saturation

5.2.3 Case B mental model of medicine availability

Case B medicine stockout arises from the inability to pay the supplier on time, as stated by the internal staff IS05:

"…if you identify such companies and pay them when due, that means you develop a good relationship with the supplier. if you have expired items or they're about to expire, you can call on their attention to come and retrieve those medications or if you have any other formulation preferences, they can be called upon to replenish your stock. When you establish a pattern for purchase or replenishment where interests are considered …this system tries to delay the supply of medication, so we go into out of stock." (IS05-01) (Abdulkadir *et al.,* 2023)

When suppliers' payments are delayed, medicine stockouts increase, as shown by the reinforcing trust loop (Figure 5.8). Pharmacists' satisfaction with the job increases when medication procurement is prioritised over "general commodities". There appears to be tension in medicines receiving the same treatment as other supplies in the hospital, and monies for medicines used to procure other services create a conflict between operating the DRF and the Treasury Single Account (TSA) policies. This conflict leads to distrust and leaking of funds that are balanced by seeking more funds from the government to stop leakage. Increasing visibility and manufacturing will not prevent stockouts unless the two conflicting policies are resolved and trust is built through transparency and information sharing. Conversely, logistics delay arising from bureaucracy of the national regulatory agency on importation of raw materials is another factor that leads to stockouts as observed by the medicine manufacturer MM47:

"In conjunction with our importers, … they send us adequate information of data on the supplies that we need and the quantity, which actually … goes through NAFDAC, that rations whatever you produce. … with their support from the international suppliers, we make arrangements of product materials that we need, they make them available and due to some logistics, there might be some delay in receiving the raw materials which can actually affect the costumers too receiving the finished product." (MM47-01)

This statement shows that delays from bureaucracy and receiving raw materials owing to logistics issues prevent time production and lead to medicine stockouts in hospitals. Hospitals do not factor in these delays in procurement planning. Sharing information with manufacturers increases visibility and reduces the pressure to continuously adjust production. These delays can be reduced using process integration and real-time visibility platforms. Security problems also result in supply delays, leading to calls for instant drone delivery of essential medicines. Integrating instant medicine delivery with drone technology improved the fill rate. Fluctuating dollar exchange rates encourage opportunism and raw material suppliers increase their prices to make more profits. When prices increase, product sales decrease, and staff motivation decreases. Increasing the purchase price of raw materials also decreases the rate of production and the productivity of manufacturers. Medicine sales promotions increase the sales of medicines and boost production for manufacturers while distorting demand. Hospitals must consider the effect of promotion on the demand data used for planning procurement which can be hindered by inadequate demand planning capacity. The MFR from manufacturers is between 70%-80%, implying a stockout of 20%-30%.

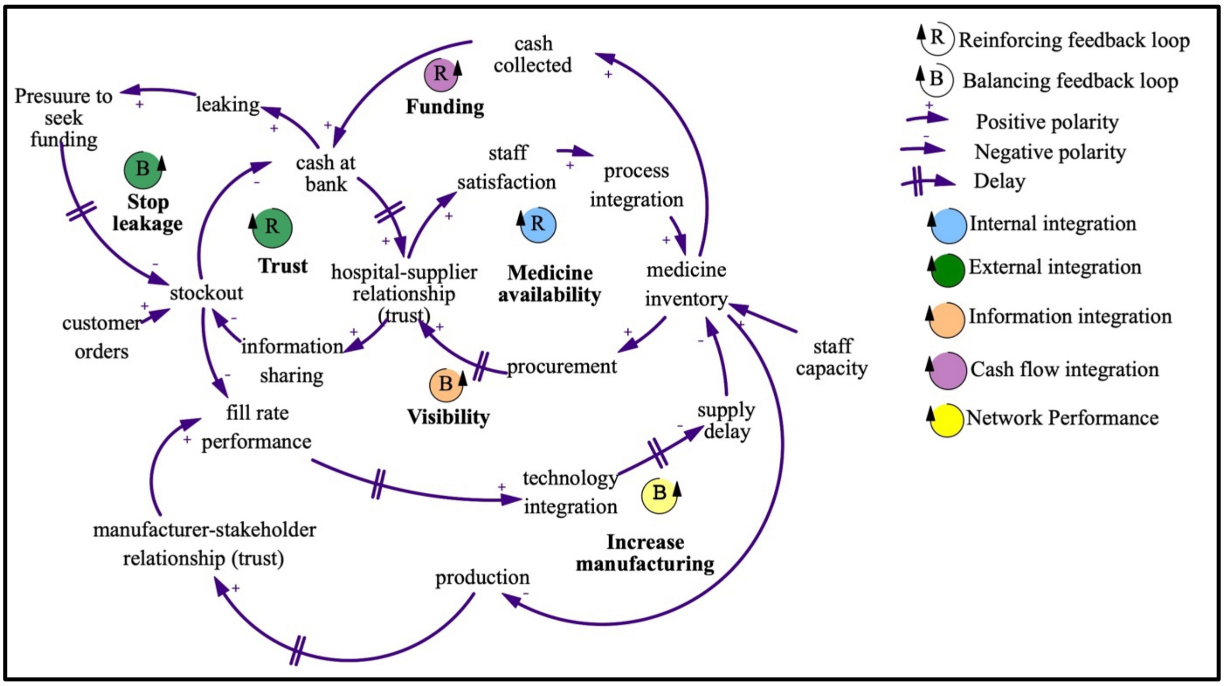


Figure 5.8: Integrated supply chain mental model for Case B participants

5.2.3.1 Causal interpretation and analysis of quotations in Case B

The internal staff feel helpless because lack of access to funds leads to stockout, as policymakers and management do not prioritise medicine procurement, as observed by IS05:

"If I had the power, I would want government to look at the purpose of setting up a drug revolving fund... because having a drug revolving fund means ... the proceed from the sales of drugs is what you use to replenish the drug and you're expected to be revolving the fund. …the government has defied those rules by merging all accounts into Treasury Single Account and it makes the DRF not to access the funds directly, it brings about a delay in the whole procurement process, at the end of the day, you go out of stock for a very long time due to inaccessibility of funds, and mostly they don't give priority to buying drugs... instead, they go on other projects with the proceeds from DRF." (IS05-10) (Abdulkadir *et al.,* 2023)

Tension in the implementation of the Treasury Single Account and the DRF policy delays procurement and increases stockout. Even though, the pharmacist should not wait to go out of stock before restocking but "procurement bureaucracy" and waiting for "like six months before drugs get replenished" defies all efforts to replenish stock. There is also the need to reconcile the differences between procurement of general commodities and medicines, as emphasised by IS05 "drugs should not be treated as general commodities" (IS05-03). Additionally, the medicine manufacturer experiences delay from bureaucracy and receiving raw materials due to logistics which prevents on time production and leads to medicine stockouts in the hospitals as noted by MM47

"In conjunction with our importers, … they send us adequate information of data on the supplies that we need and the quantity, which actually ... goes through National Agency for Food, Drug, Administration and Control (NAFDAC), that rations whatever you produce or stuff like that. … with their support from the international suppliers, we make arrangements of product materials that we need, they make them available and due to some logistics, there might be some delay in receiving the raw materials which can actually affect the costumers too receiving the finished product." (MM47-01)

Logistics constraints arising from insecurity in the use of road transportation to deliver medicines to hospitals is a challenge for MM47 leading to a wish for the use of drone delivery to minimise time wastages and loss of lives "use drone deliveries, so with that we don't need to risk anybody's life or time". The unwillingness to deliver medicines to insecure locations "where the driver will be scared and say I don't want to go to the area" increases the risk and delivery cost, making medicines more expensive. MM47's wish to use drone delivery to minimise the risk from insecure road networks could be related to the deployment of drone logistics in Case A, which is also provided by the same manufacturer. This statement highlights the need for shared drone deliveries to minimise risk for the entire network. Because Case A benefits from drone logistics, manufacturers supplying other hospitals can collaborate with Case A and the logistics service provider to share drone deliveries. Integrating instant medicine delivery with drone technology improved the fill rate. Another challenge mentioned by MM47 is the fluctuating dollar exchange rate which encourages opportunism, as raw material suppliers increase their prices to make more profit. When prices increase, product sales decrease, leading to staff demotivation.

"Naturally, the importers, raw supply providers I feel there should be like a set goal of understanding because the economy of the country …, by this quarter we will pay you and these are the materials we will need, even without change in dollar, because change in dollar affect a lot of things and once there's a change, the supplier might be greedy …. You know business is about profit, it's not about friendship or family. So, everybody wants to maximise every way they can make profit, so if there's an agreement that okay, this are the things we want and these are the payment upfront, … it will help a lot, so that the economic situation won't affect the productivity of the company." (MM47-07)

Competition between manufacturers and raw material suppliers makes it difficult to meet their obligations in delivering medicines to hospitals on time at the most responsive price, as they are at the mercy of suppliers. When everyone in the network tries to maximise their profits, everyone loses as customer satisfaction becomes elusive. On the other hand, a lack of hospital teamwork, as the pharmacy's request is not respected and prioritised, leads to staff dissatisfaction, as noted by IS07-02 (Table 5.6). Delays in payments for suppliers result in stockouts. The reinforcing procurement loop which increases order fulfilment in hospitals, has a balancing payment feedback loop of delayed supplier payments and fewer future deliveries (Figure 5.9). See Case B interview analysis in Appendix X.

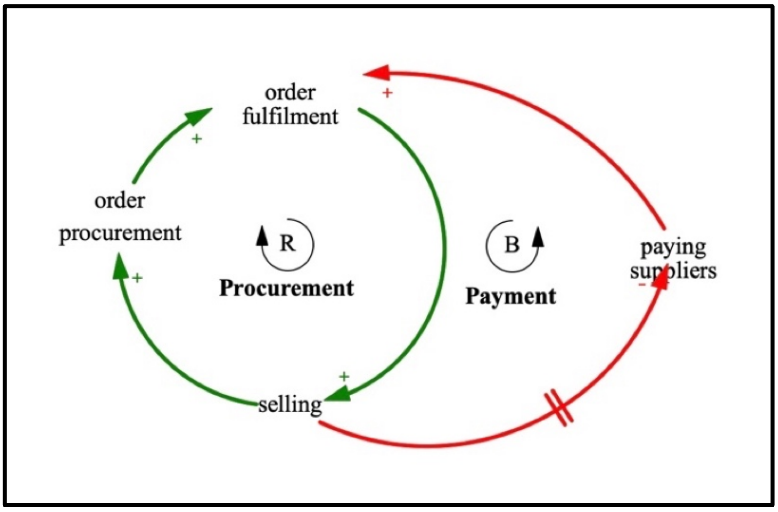


Figure 5.9: Procurement and payment loops leading to stockout in Case B

Analysing the causes of stockouts across variables in Case B shows some similarities to Internal Staff (IS) and Medicine Manufacturers (MM) in information sharing and fill rate (Table 5.6). Differences range across participants; however, only IS05 identified cash at the bank and leaking of funds as causative of stockout, while IS07 views medicine production as a source of stockout.

Table 5.6: Analysis of variables leading to medicine stockout within Case B

Variables causing stockout in Case B	IS05	MM47	IS07	IS22
Hospital-supplier relationship (trust)	√	-	-	√
Cash collected	√	√	-	-
Information sharing	√	√	√	√
Medicine production	-	-	√	-
Fill rate	√	√	√	√
Procurement	√	-	√	√
Technology integration	√	√	√	-
Leaking	√	-	-	-
Customer satisfaction	-	-	√	√
Cash at bank	√	-	-	-
Staff satisfaction	√	-	√	√

IS07 stated that a lack of teamwork manifests in the feeling of being disrespected, resulting in staff dissatisfaction. Unhappy staff members become resentful when they must adjust medicine on order. Tension between the procurement team and pharmacy with staff members caught in the middle of providing the right medication for prescribers while justifying the need for procurement. Additionally, this tension spills into the payment of suppliers as accounts delay paying suppliers, leading to stockouts (Table 5.7).

Table 5.7: Evidence for increasing teamwork and internal performance

ParticipantNumber-Quote number) "... variables in Phrase(s)" (word count in variables/total word count in causal statement)	**Phrase(s) from participant quote denoting model variables**	**Interpreted model variables**	**Causal link between model variables (→=causal link, --||→=causal link with delay, +/-=positive or negative polarity)**	**Themes from participant quotes**
IS07-02) "to improve the relationship among the interdepartmental teams is for other departments to understand the request generated by the pharmacy. Account also needs to understand that these products are cost effective. … after specified period of time suppliers need to be paid. ...to improve inter-relationship, what pharmacy sends as a request should be respected and they should understand if there's any ambiguity procurement should make effort to understand with pharmacy department for clarity, ...purpose. after the product has been	- relationship - request generated - cost effective - period of time - delay - supply is made - paid - respected	Teamwork Order procurement Purchase price Delay Order fulfilment Paying suppliers Staff satisfaction	Teamwork→+Order procurement→-Purchase price→-Order fulfilment--//→-Paying suppliers→+Supply delay→-Staff satisfaction→+Adjusting medicine on order	Internal integration There is no teamwork as pharmacy request are not respected and prioritised leading to dissatisfaction. Payments of suppliers are delayed resulting in stockouts.

supplied, accounts section … not delay the payment of those companies because delay in their payment will affect future supplies. The doctors and nurses should let us have feedbacks about drugs if they are giving the intended reason for procurement. If not, pharmacy will need to make re-adjustments at the next procurement by re-considering a different supplier". (136/185)	- affect future supplies - re-adjustments	Supply delay Adjusting medicine on order		

Another concern for IS07 appears to be medication quality and safety as stated below:

“...For getting medicines into hospital, the policy has changed a bit now with the introduction of procurement units. This issue has already caused a little rift and has tainted the relationship. The procurement department needs to understand why the pharmacy is making reference to particular medication. … with the coming of procurement, we're really trying to build the relationship ... because our procurement department staff are not medically related. they are neither pharmacist, doctors nor nurses. They are administrative staff. So, their knowledge about drugs is very limited. So, we have always encouraged that procurements should consider obtaining these drugs from the source, suppliers that are the makers or the major distributors because that will ensure that the products are coming from the right sources and if there's any issue, of course we know where to face”. (IS07-04)

“Any issue” captures the fears of medication safety and integrity of medicines supplied as the procurement staff do not have the capacity to identify different medicines. This statement shows a lack of teamwork, trust, and inadequate process integration. It also points to a lack of trust in the procurement process of the organisation. Communication friction between the teams prevents stocking of adequate medicines at the right time and paying suppliers which reduces trust and customer satisfaction. The tensions between teams must be resolved for any meaningful progress in improving the MFR.

5.2.3.2 Case B conceptual model saturation

The new variable groups of interviews for Case B’s quotation interpretation were IS05, IS22, IS07, and MM47, while the validation saturation group included IS38 and IS36. The cumulative variables for each participant were identified and recorded for group one and rearranged in ascending order. From the second group of interviews, IS38 was analysed, and the variables were compared to the first group to identify new variables. No new variables are identified in this study. This was followed by IS36 with a zero percent variable saturation point before IS38 (Figure 5.10). The causal link, casual loops, and time delay saturation were achieved before IS38 (see Figure 5.11, 5.12, and 5.13, respectively).

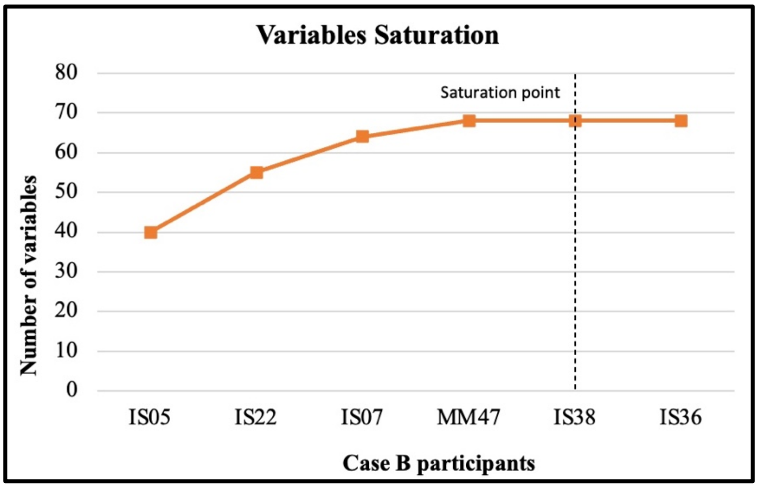


Figure 5.10: Case B conceptual model variable saturation

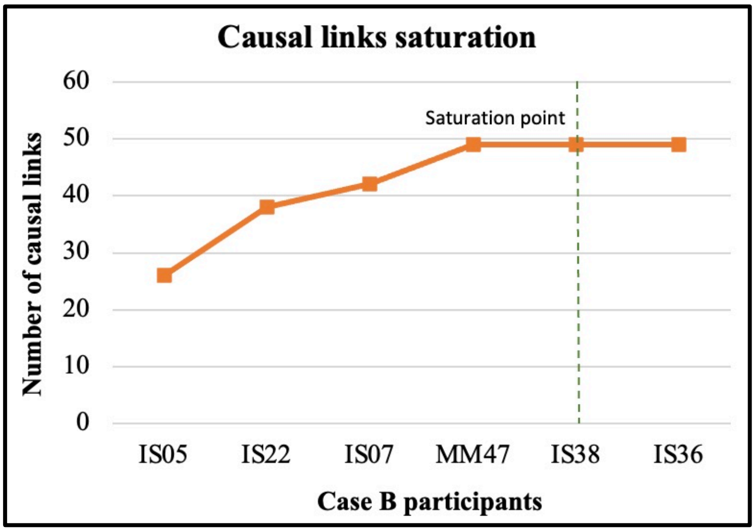


Figure 5.11: Case B conceptual model causal links saturation

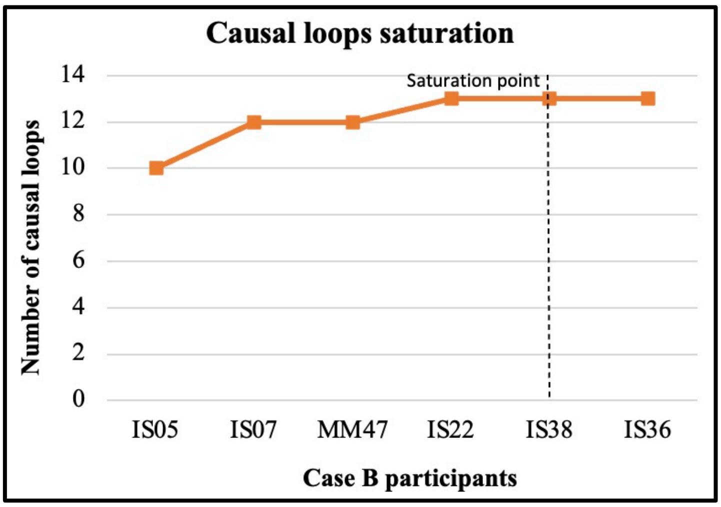


Figure 5.12: Case B conceptual model causal loops saturation

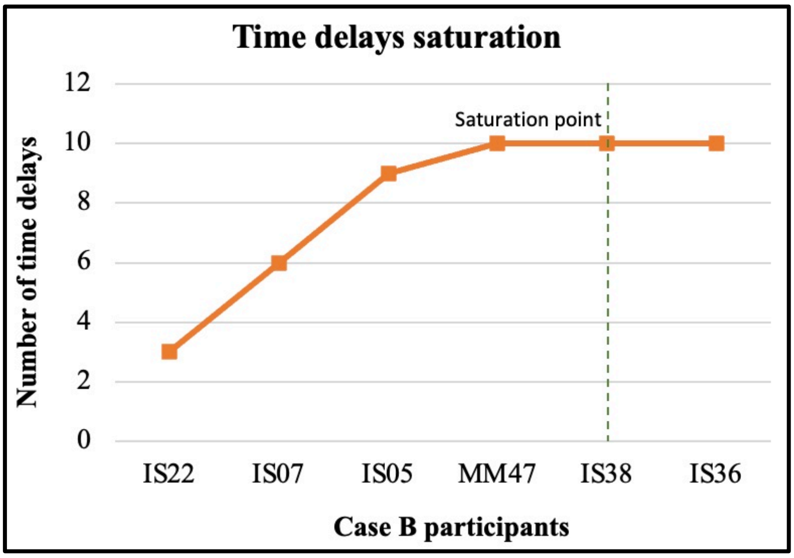


Figure 5.13: Case B conceptual model time delays saturation

5.2.4 Case C mental model of medicine availability

Different departments must work together to source and execute procurement processes. Bringing the team together physically is difficult without supporting technology to provide visibility for information. The time delays from physical engagement throughout the process foster mistrust among the team members. The use of ICT tools to communicate and improve relationships with medicine vendors increases transparency and trust in the process. Suppliers fulfil more orders to the hospitals and cash at bank increases, leading to a reinforcing loop of paying outstanding invoices and buying medicines, as noted by internal staff IS02:

"After quantification and medicines selection, we ask suppliers to quote for drugs before sending it to us. we improve the process by putting the list of medications in a flash drive and sharing with suppliers. I envisage a process in which there will be an interface with the organisation and the supplier. An interface that allows suppliers to key into the system from their end automatically. All wasted time (1-2 weeks) in the current system will be saved and improve working relationship with the suppliers. Lack of immediate payment for supplies delivered to the hospital … hinders working relationship with the suppliers." (IS02-06) (Abdulkadir *et al.,* 2023)

Although there is some use of technology in hospitals, the lack of a digital platform for order processing delays procurement. Another staff member, IS11, argues that abiding by financial regulations and the Public Procurement Act, ensures that there is money available to procure medicines:

"…we cannot do this procurement without the procurement unit. …the accountant will give us the financial implication. Before you procure, there must be availability of funds. … management must be aware the cost implication of these medicines to be able to evaluate problems, where there's paucity of funds can become a problem. In recent times we have problems with availability of funds and management has to make sure that they work around the clock to ensure that funds become available. … if information does not get to them, the condition cannot be resolved." (IS11-02)

This statement underscores the importance of the visibility and transparency balancing loop, which attempts to correct the reinforcing medicine availability loop shown in Figure 5.14. Sharing information with the hospital team ensures medicines are procured and helps doctors to know what to prescribe to patients reducing shrinkages and expiries leading to better fill rates. Transparency in cash flow for medicines increases medicine inventory, as more medicines can be procured.

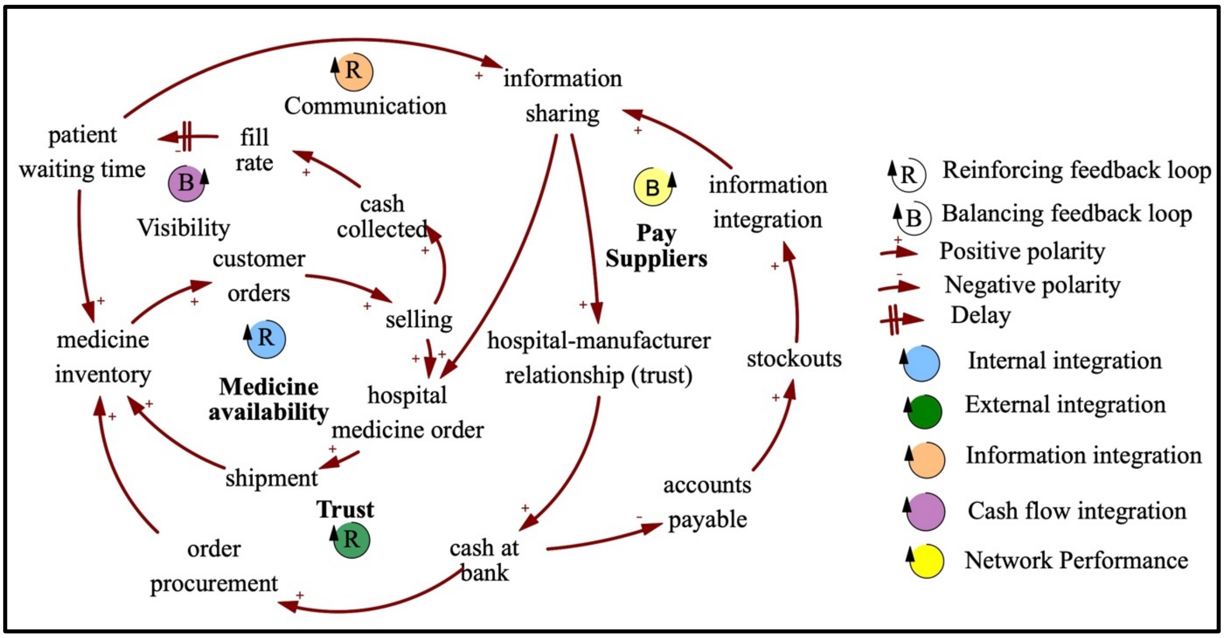


Figure 5.14: Integrated supply chain mental model for Case C participants

The SC appears to be in a constant rush to provide medicines through emergency procurement, as stated by IS21.

"…we have emergency drugs in a situation whereby we don't want too much out of stock… we have what we call emergency drugs committee. Whenever there is no … drugs available, we rush into the committee to make drugs available for the patient. … we work …with the suppliers. The moment we observe that we don't have drugs, ... the procurement write immediately, … we rush in… to make things available, we now call the pharmacist…maybe they make the supply. Sometimes they do supply without … paying them… that is how they will bring it before we now pay them". (IS21-03)

This statement also shows that apart from being stuck in the emergency procurement trap, IS21 is also unsure if the supplies are received in the pharmacy. IS21 believes that incentivising staff members will improve working relationships and performance. The assumption that incentive will boost staff productivity and "make them work, even out of their time" leads to staff satisfaction and customer integration. The government sometimes donates free medicines to hospitals, and the free medicines get mixed up with the DRF medicines, leading to confusion as patients who can afford medicines get refunded and staff divert patients away from depositing cash, leading to excess stock in the revolving fund as medicines already procured are not sold and funds become depleted as donations replace DRF medicines. These donation-revolving fund tensions could also explain why suppliers might not get paid for order fulfilment and the resulting excess stock leading to expiring inventory. When medicines expire in the hospital, it leads to the leakage and loss of funds which collapse the DRF program. Supplier promotion of medicines to prescribers influences prescription patterns and disrupts the procurement cycle by creating demand uncertainty. The lack of visibility of available and expiring medicines leads to stockouts.

Analysing the causes of stockouts across variables in case C indicates some similarities across participants regarding trust, information sharing, and fill rate. Differences vary across participants, with IS02 identifying patient wait time, hospital ordering process, and shipment as causes of stockout. Conversely, IS11 identified accounts payable as the reason for medicine stockout (Table 5.8). See Case C interview analysis in Appendix XI.

Table 5.8: Analysis of variables leading to medicine stockout within Case C

Variables causing stockout in Case C	IS02	IS11	IS20	IS21
Hospital-supplier relationship (trust)	√	√	√	√
Cash at bank	-	√	√	√
Information sharing	√	√	√	√
Patient waiting time	√	-	-	-
Fill rate	√	√	√	√
Procurement	√	-	√	√
Hospital medicine order	√	-	-	-
Accounts payable	-	√	-	-
Shipment	√	-	-	-
Selling	√	√	-	√

5.2.4.1 Causal interpretation and analysis of quotations in Case C

Internal distrust and the perception of a "hidden agenda" by internal staff IS02 show the reasons behind medicine stockout and weak internal integration across the SC. External stakeholders can perceive a lack of internal trust, leading to erosion of trust and decreasing government funding, as stated by IS02 (Table 5.9) and represented in the trust and funding loops (Figure 5.15). The need for transparency and visibility in cash flow for medicines increases medicine inventory, as more medicines can be procured and restored by IS11. Visibility can be achieved with technology to enable procurement with faster flows of prescription orders and cash flows with a real-time collection process. Sharing information with the hospital teams ensures medicines are procured and helps doctors to know what to prescribe to patients reducing shrinkages and expiries leading to better fill rates. Problems with cash collection deplete cash at banks, and when hospitals are unable to pay suppliers, medicines are stocked out, making it difficult for all stakeholders. Excessive delays in paying suppliers lead to bad debt and stockouts of medicines. When medicine manufacturers collect loans for production and do not get paid for supplies, the company can collapse which also affects hospitals. Building employee capacity and implementing benefits will increase trust, and the knowledge gained will be channelled to reduce expiries and improve fill rates.

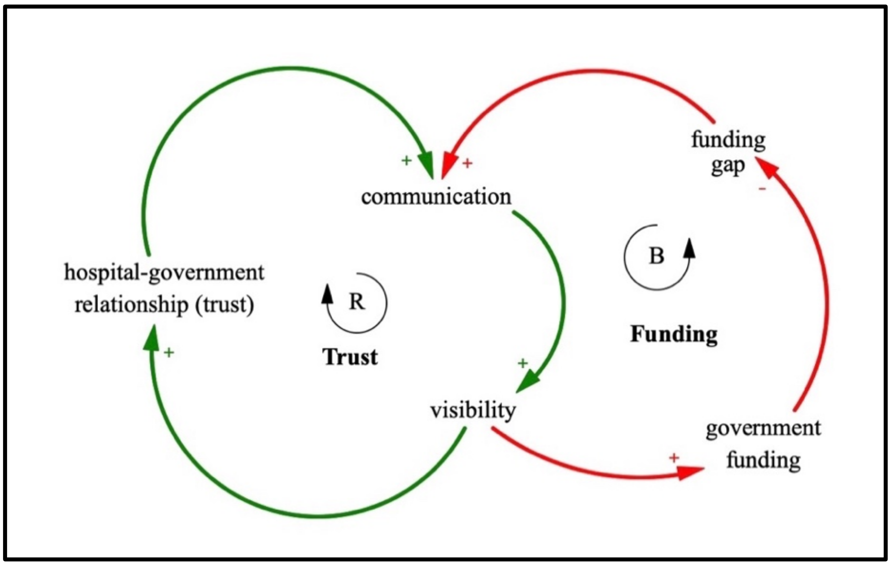


Figure 5.15: Trust-funding loop leading to medicine stockout in Case C

Providing information and medicines to patients at hospitals reduces exposure to fake drugs in open markets. Increasing transparency and reducing corruption allow cash to grow and improve the fill rate, as noted by IS11.

"We have to follow laid down policy and regulations, failure to meet guidelines will cause obstacles or ... fail to meet expectation of stakeholders. …anticorruption and transparency… I advise people to stick to guidelines and procedures. It helps us to evaluate and improve guidelines for review but when you cut corners, you will not make any influence and performance will suffer." (IS11-15)

Cutting corners or sharp practices in the supply chain deplete internal and external stakeholder trust, while payment for supplies builds trust among partners. The lack of internal transparency leads to staff dissatisfaction and helplessness, as noted by IS20.

".... the main bottleneck we have is ... during payment after procurement ... it has to undergo a lot of processes from one office to the other, and this process can take up to in fact I cannot say, more than a month, two, three, four months, depends on what the situation is on ground then. ...to improve this process, I think we can facilitate it as within one week it is possible, because I think I was here when we use to do this process within two weeks latest, but now, I don't know how to explain it, may be if you can see the people from account and audit may be in a better position to explain that part, but as a pharmacist, I know we have been trying and we have not changed because we are the one that are here, when I said it is two weeks that will give supplier and they come and collect their money, we are still here today. ... you can see the transformation is not actually with us, others will be able to explain that". (IS20-02)

This statement shows that there is no transparency because IS20 cannot explain what is happening in the system. These departments work in silos without teamwork. There is accusations and finger pointing, the 'us' versus 'them' syndrome. The supply chain needs to fix internal problems among the staff before attempting to work with suppliers. Distrust has fragmented the processes, and patients suffer from medicine stockouts. Staff have limited knowledge of digital technology, and manual methods of sharing information can cause delays. The financial management rating had the poorest performance at 20% and an MFR of 50-60%. The disappointment in accounts departments not informing "government fast" enough to improve funding for medicine procurement leads to helplessness and staff demotivation.

Table 5.9: Evidence for increasing trust and funding towards network integration

ParticipantNumber-Quote number) "... variables in Phrase(s)" (word count in variables/total word count in causal statement)	Phrase(s) from participant quote denoting model variables	Interpreted model variables	Causal link between model variables (→=causal link, --||→=causal link with delay, +/-=positive or negative polarity)	Themes from participant quotes
IS02-16) "With government, I think the only way we can improve is to remove … bottlenecks. …The only way to remove bottlenecks is … government … to give funds, … directly to the hospitals for certain activities. The hospitals should strictly use the funds for the intended purpose and not divert funds …, funds allocated for drugs should not be used to fund building or other capital projects in the hospital. … government can strengthen institutions through … improving communication. …through digitalization. There should be transparency and accountability in use of funds at the hospital." (94/158)	- remove … bottlenecks - give funds - not divert funds -improving communication -transparency and accountability - intended purpose	Time delays Government funding Hospital-Government relationship (trust) Communication Visibility funding gap	Hospital-Government relationship (trust)--//→+ Communication→+ Visibility→+ Government funding→-funding gap	Network integration Reduced trust and communication decreases transparency and government funding

Source: Abdulkadir *et al.* (2023)

5.2.4.2 Case C conceptual model saturation

The new variable group of interviews for Case C quotation interpretation was IS21, IS20, IS02, and IS11, whereas the validation saturation group included IS17, IS19, and MM42. The cumulative variables for each participant were identified and recorded for group one and rearranged in ascending order. From the second group of interviews, IS17 was analysed, and variables were compared to the first group to identify new variables. Two new variables were identified and the cumulative values were plotted on a graph (Figure 5.16). Then, IS19 had and MM42 had zero percent variables with saturation points before IS19. The causal link, casual loops, and time delay saturation were achieved before IS19 (see Figure 5.17, 5.18, and 5.19, respectively).

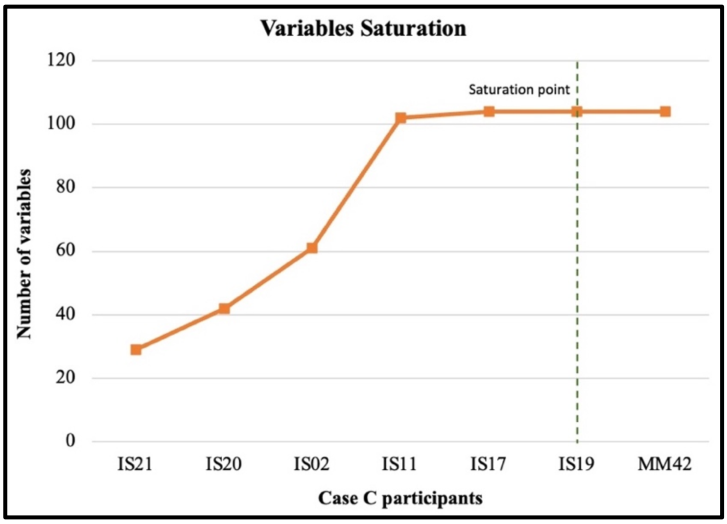


Figure 5.16: Case C conceptual model variable saturation

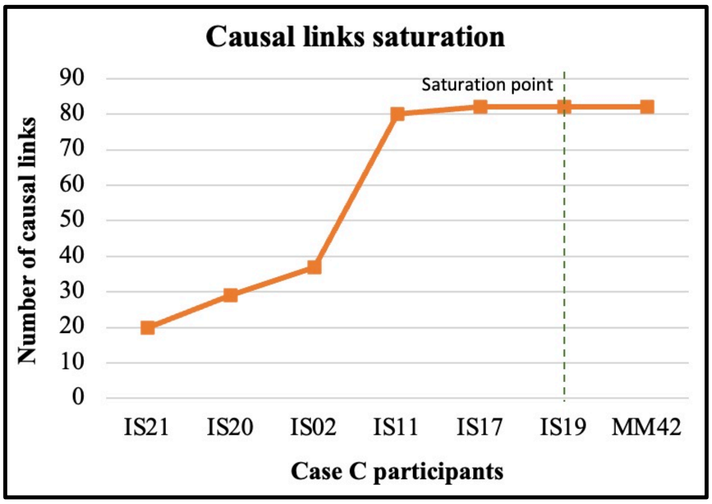


Figure 5.17: Case C conceptual model causal links saturation

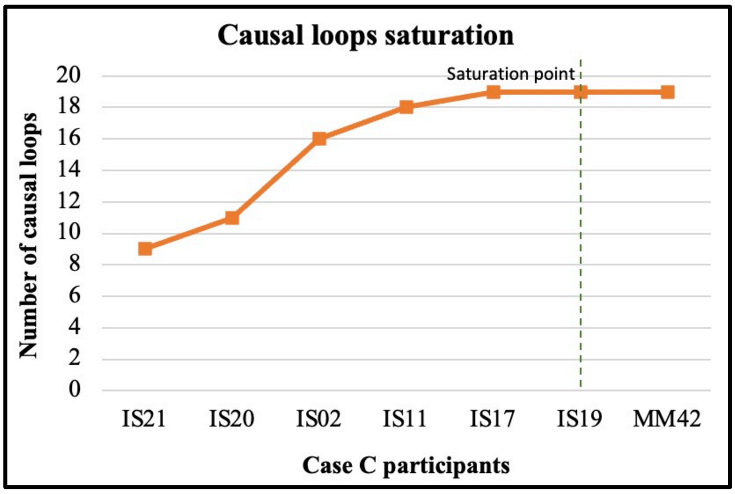


Figure 5.18: Case C conceptual model causal loops saturation

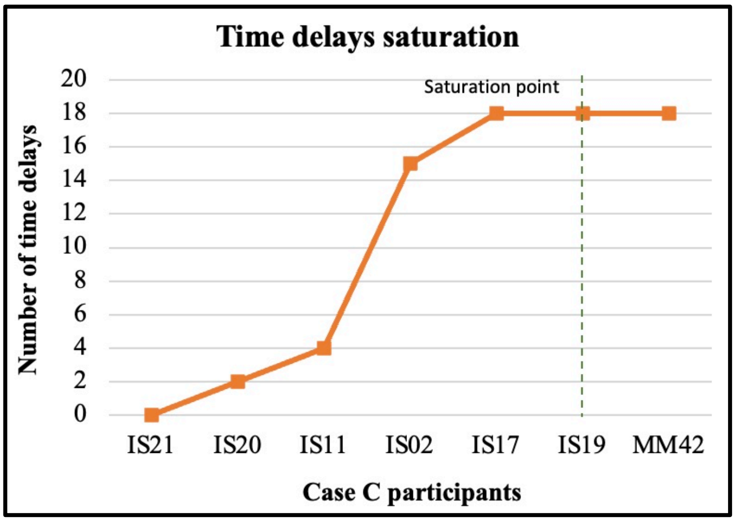


Figure 5.19: Case C conceptual model time delays saturation

5.2.5 Case D mental model of medicine availability

In Case D, information is shared when there is a need for products, which hamper planning by suppliers and require real-time visibility for an effective supply plan. IS04 explains how the SC shares information.

"we share information with our patient's, some patients make request through phone calls to find out about drugs that are not readily available e.g …we display our drugs prices list publicly so that patients can know the prices of medicines. we interact with suppliers by keeping stock inventory of the patients. … purchase drugs directly from them or through contracts. For management, we periodically send them reports quarterly on all activities." (IS04-05) (Abdulkadir *et al.,* 2023)

It appears that information is only shared when requested, and the documentation of reports is manual which delays information sharing. The organisation does not have digital technology or the capacity to run the SC, but there is a sense of curiosity about the benefits of operations automation with real-time platforms. Demand uncertainty arising from unpredictable prescribing behaviours of physicians was also cited as a reason for medicine stockouts from supplier delays. These changes can be linked to promotional activities from suppliers which change the prescription patterns of medicines. The use of manual inventory management techniques to reduce shrinkage, pilferage, theft, damages, and expiries is inefficient. Managers have difficulty differentiating stockouts from leaking inventory and real demand. Even when the SC tries to correct the gap by buying more products from suppliers and honouring commitments to pay for deliveries, hospitals are still unable to satisfy patients' demand as shrinkage continues to deplete the stock. Building staff SC digital capacity increases staff satisfaction and productivity to minimise shrinkage and increase the fill rate for customers. IS04 explains (Table 5.10) how the hospital tries to balance stockout from shrinkage by reordering medicines in a balancing restock loop which becomes ineffective as medicines continue to shrink (Figure 5.20). Inadequate internal process alignment allows for process exploitation and gaming of the system by suppliers quoting the lowest price to win a bid. IS08 describes how suppliers change prices after winning bids, claiming price increases which displeases the staff:

"... there will be a better result if the pharmacist was allowed to do whole necessary parameters because the accounts, the procurement department and the Audit department don't really understand the implications of when we say we need a certain medicine from certain companies. Sometimes we know some of our companies do price adjustment to quote lower for a drug but when asked to supply, they cannot supply. ... the hospital policy is the lowest bidder gets the supply. If pharmacy is allowed to take charge of all those areas, all those preambles to sought out the companies that will deliver irrespective of the cost implication, and the accounts can come in as independent, it will make the procurement process much faster and better, because what we have now is out of stocks, some companies cannot supply because of price change, there are complaints. Once the procurement is done, the cycle cannot be repeated three to four months to meet the quarterly resupply". (IS08-02)

This statement shows how suppliers try to game the system to win bids and then hike prices when asked to supply medicines which leads to the failure of the procurement process as the cycle is disrupted and supplies are delayed. The hospital needs to form strategic partnerships with key suppliers to achieve a win-win situation for the network and reduce opportunism.

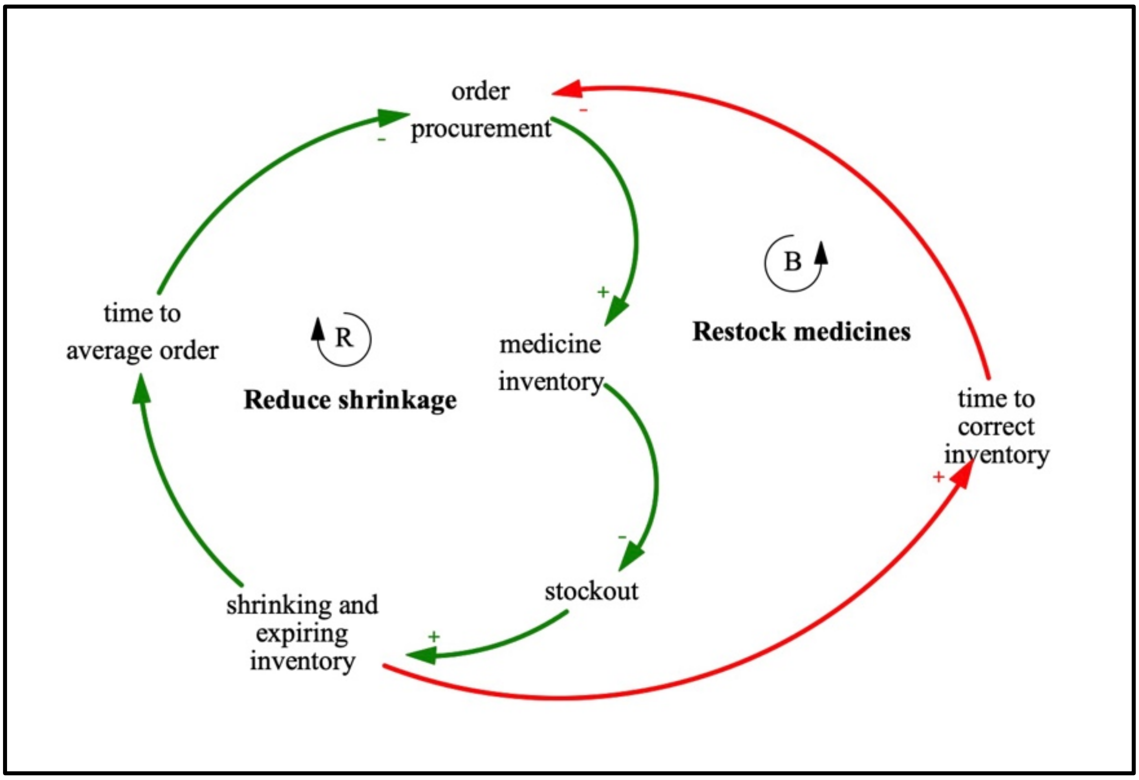


Figure 5.20: Replenishment and restocking loops for Case D

Figure 5.21 shows the shared mental model of Case D. See Appendix XII for Case D interview analysis.

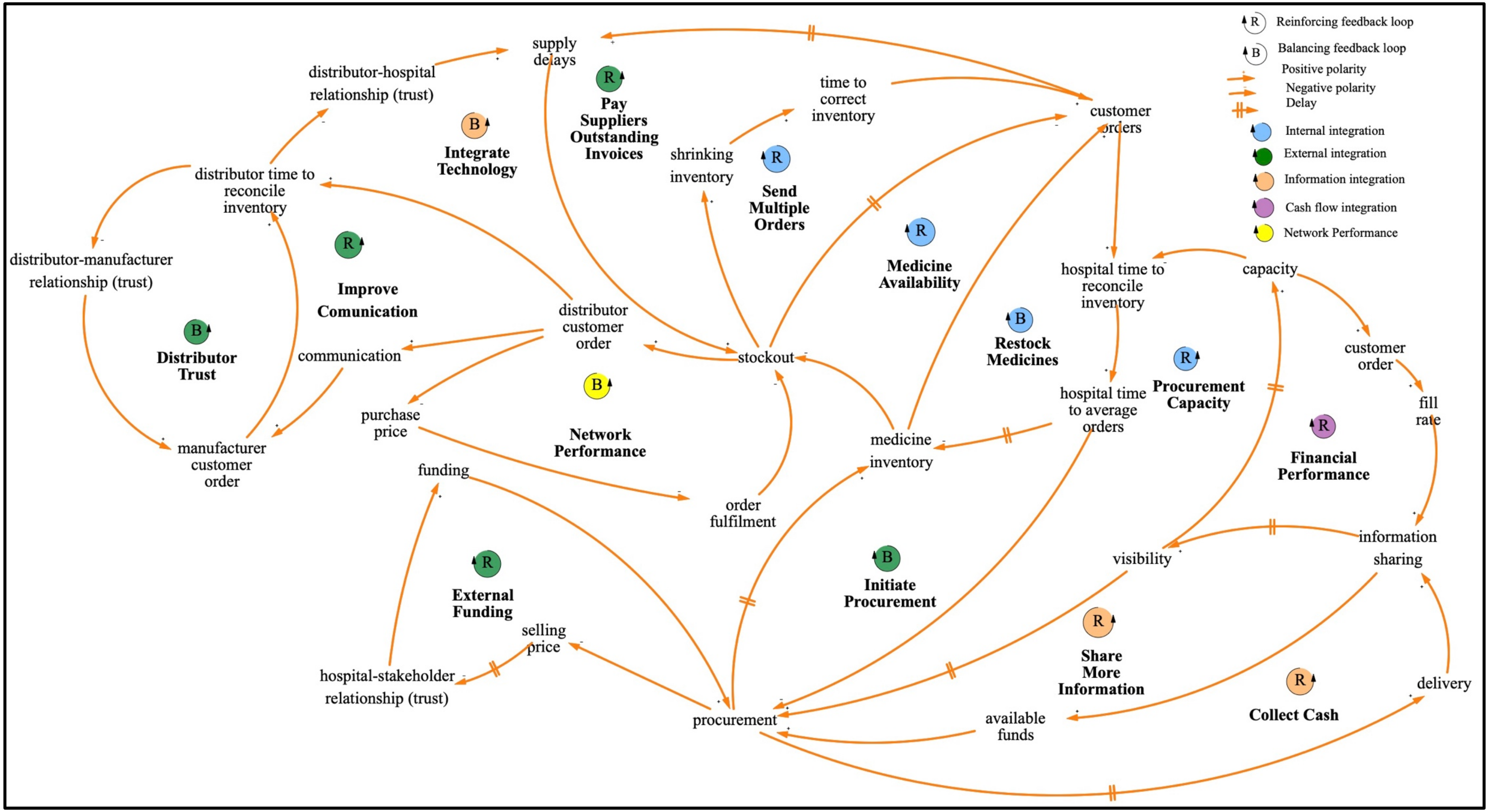


Figure 5.21: Integrated supply chain mental model for Case D participants

Table 5.10: Evidence for reducing shrinking and expiring inventory to improve medicine fill rate

ParticipantNumber-Quote number) "... variables in Phrase(s)" (word count in variables/total word count in causal statement)	**Phrase(s) from participant quote denoting model variables**	**Interpreted model variables**	**Causal link between model variables (→=causal link, --‖→=causal link with delay, +/-=positive or negative polarity)**	**Thematic identification from quotes**
IS04-11) "…we keep adequate record so that when we need drugs we can order quickly. inventory accuracy improve the supplies and minimising wastages through pilferages, theft, damages and expiries increases availability of drugs. for patients, by keeping accurate records, …don't allow drugs to finish before requesting for more keeps drugs readily available. (/58)	- adequate record - order quickly - inventory accuracy -wastages through pilferages, theft, damages and expiries - availability of drugs - allow drugs to finish	Time to average orders Order procurement Time to correct inventory Shrinking and expiring inventory Medicine inventory Stockout	Time to average orders→-Order procurement →+Medicine inventory→-Stockout→+ Shrinking and expiring inventory →+Time to correct inventory	Internal integration Shrinking inventory plays a huge role in stockout of medicines by distorting the accuracy of medicine records and delaying replenishment.

Source: Abdulkadir *et al.* (2023)

The feeling of frustration on the part of staff as medicines is never enough to serve customer needs and is attributed to relationships between departments and process integration, as described by IS08:

“We have a former procedure, which was changed when this new administration came onboard, the current administration insist that procurement must take charge of everything. Other departments just come in as supporting staff, but procurement is leading the whole thing. So, irrespective of what our patients say, in terms of this product works better for them and all that, we have little to say when it comes to procurement meeting, ours is to make provision of what we need and submit to the procurement office. They are the ones that ensure the integrity of the whole procurement process. ... In terms of not meeting up on patients or clients need which we normally prepare on a quarterly basis. Some of these drugs might have finished before the end of the quarter, or some might not have been supplied. And once the process is over, you don’t get any supply until the next quarter. There's little or no much say or interaction between clients, pharmacy and the whole procurement process. ...we may not get the drugs we want ... because of the bottleneck of administration but we still have to let the system run”. (IS08-03)

The statement above clearly shows the need for change management as the introduction of a new process has disrupted all operations due to mistrust and misalignment of the procurement process with “meeting up on patients or clients need”. The staff are not working together as “There's little or no much say or interaction between clients, pharmacy and the whole procurement process”. Trust and harmonious working relationships towards a shared goal are critical for improving the MFR. The need for medicine user departments to actively engage in the procurement process as a cross-functional team was expressed by IS08:

“... user department would play a major role in the procurement process of that particular department because they know what they want, to satisfy the clients. They know what timespan and what quantity of drug will last for a particular time... looking at price templates and determining who is best suitable to supply ... it will go a long way in trying to strike a balance between clients, user department and the procurement process...” (IS08-04)

The lack of teamwork within hospitals affects suppliers, as the medicine distributor explains the need for better alignment:

"…to have more harmonious relationship than what we have, and we're working towards it. And then again, to improve on our database, because there are some loopholes that needed to be corrected as to how we keep those data". (MD40-02)

"… improving on our interactions with them, so that we have more information at our disposal than what we have now. That will improve working relationship with them" (MD40-04)

The hospital struggles with internal relationships which also affects suppliers' internal and external trust. An increase in hospital orders leads to an increase in distributor selling prices and stockouts at hospitals, as explained by MD40:

"… our customers normally give us a list of drugs to quote and normally we respond back by giving them our prices and the type … the products that we're going to give and probably the expiry date in some cases, and we also interact with them to tell them things that are not available right now, for where there are issues that needed to be resolved". (MD40-06)

Since Case D only collects medicines with expiry dates above two years as noted by IS08 "...we try as much as possible not to collect drugs that have less than two years..." and the prices quoted by suppliers are based on expiry dates as described by MD40 "giving them our prices and the type … the products that we're going to give and probably the expiry date in some cases", this could explain the discrepancies in prices depending on expiry dates of medicines. The SC operates manually, and the supplier has minimal digital capacity. Improving internal and external digital capacities will increase sales and hospital fill rates. Measuring and managing the fill rate drive the availability of medicine and financial performance. The absence of process integration is taking a toll on medicine manufacturers, as MM39 notes.

"…if we have a stock in maybe in Kaduna, so … lead time will reduce to if the order is sent directly to Lagos from the organization, irrespective of whether the rep comes around because the rep goes from one organization to the other. … they can send their order directly to the office or to the manager, then again, if payments is as at when due…, supplying them periodically and on time, then if the organization … can do in such a way that you have a level of the stock, … we don't have to come often to see them to check the order so that they can periodically be giving us standing orders so that we don't have to run out of stock, it will enhance our operation." (MM39-02)

Digital integration and information sharing will allow the manufacturer to see the hospital needs in real time and minimise delays from physical visits by the MM39 company representative "the representative visits these organizations from time to time to check the stock level and to move around to place order". In addition to visiting hospitals, the representative serves as an interface.

"... the interface is the one that moves around to collect money, …moves on to see the procurement to tell them that a particular products level has reduced significantly, and … pursuing the order at the same time, … moves around in the hospitals to ensure that products are prescribed … to ensure that the products … leave the store the same time will be dispensed to the patient." (MM39-03)

This statement shows that the company representative is the bond between hospital teams as well as between the manufacturer and the hospital. This could explain why the teams do not talk to each other because they are all talking to the company representative. This practice is detrimental to internal and external performance, and the patient suffers stockouts and delays. Technology can connect teams faster and communication builds stronger cohesive teams to drive operations. The visibility of operations improves information sharing about medicines and trust in the system, while procurement increases with trust. Trust is the basis of process integration and compliance with regulatory bodies to boost the production capacity. The fluctuating exchange rate between the dollar and naira makes it difficult to pay for the import of medicines and raw materials, leading to losses for manufacturers from the government exchange rate policy (Figure 5.22). Analysing the causes of stockouts across variables in case D indicates some similarities across participants in information sharing. Differences vary across participants, with IS04 and IS08 identifying purchase and sell prices as key variables for stockouts. On the other hand, manufacturer MM39 was only concerned with the purchase price of raw materials, while distributor MD40 identified the purchase and sell prices as middlemen. IS04 and MD40 also mentioned time to reconcile and correct the inventory as critical to the MFR. Hospitals and distributors worry about shrinkage and expiring inventory, as noted by IS04, IS08, and MD40 (see Table 5.11).

Table 5.11: Analysis of variables leading to medicine stockout within Case D

Variables causing stockout in Case D	IS04	MM39	MD40	IS08
Hospital-supplier relationship (trust)	-	-	-	√
Distributor-hospital relationship (trust)	-	-	√	-
Capacity	√	-	√	√
Information sharing	√	√	√	√
Sell price	√	-	√	-
Fill rate		√	√	√
Procurement	√	√	-	√
Visibility	√	√	√	-
Shrinking inventory	√	-	√	√
Delivery	√	√	√	-
Purchase price	-	√	√	√
Selling price	√	-	√	-
Supply delays	√	-	-	-
Time to reconcile inventory	√	-	√	-
Time to average orders	√	-	-	-
Time to correct inventory	√	-	√	-
Funding	√	-	-	√
Communication	-	-	√	√
Order fulfilment	-	√	√	√
Hospital-stakeholder relationship (trust)	√	-	-	√

5.2.5.1 Causal interpretation and analysis of quotations in Case D

When manufacturers pay suppliers on time, they buy more medicines, and stockouts decrease. Reducing stockouts from manufacturers increases the fill rate at the hospital. Manufacturers use digital technology to accelerate communication and increase medicine order fulfilment through third-party logistics. Raw material procurement has a reinforcing foreign exchange loop and balancing procurement loop (Figure 5.22).

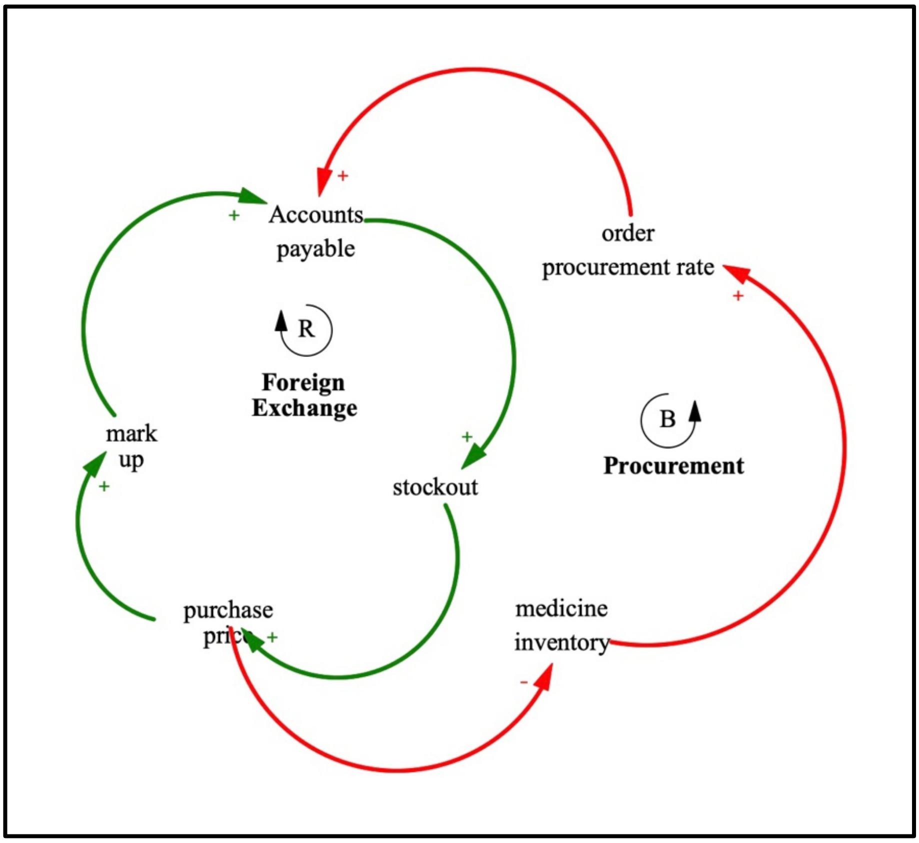


Figure 5.22: Foreign exchange and procurement loops for Case D

When the dollar exchange increases, the manufacturer's account payable also increases as the raw material becomes expensive, and the manufacturer must pay more to produce medicines. An increase in the selling price at the hospital decreases customer orders and fewer people buy medicines. The procurement balancing loop attempts to correct this feedback by ordering less raw material, thereby decreasing production and accounts payable. When prices decrease, demand increases and manufacturers must produce medicines faster to meet demand. This foreign exchange-procurement cycle leads to uncertainty for the manufacturer which translates downstream as a medicine stockout for patients. Suppliers' practice of changing prices after winning bids could also be due to exchange rate uncertainty (Table 5.12)

Table 5.12: Evidence for dollar exchange rates uncertainty on medicine procurement

ParticipantNumber-Quote number) "... variables in Phrase(s)" (word count in variables/total word count in causal statement)	**Phrase(s) from participant quote denoting model variables**	**Interpreted model variables**	**Causal link between model variables (→=causal link, --||→=causal link with delay, +/-=positive or negative polarity)**	**Themes from participant quotes**
MM39-08) "… there are some … government policies that may not make the drugs to be available as at when due. … when you import drugs, and you are to repatriate the money, the exchange rate is such that when you are the repatriate the money, … product that has been sold for a particular price and you have gain, and you are repatriating this money and dollar has increased, so it will affect the profitability of the of the company. we ensure that all our SKU's, our stock keeping units are always available at any given time. …we ensure that those products …have reorder level. There could be … a	- not make the drugs to be available - stockout - when due - a period - import drugs - repatriate the money - price - profitability	Stockout Delay Order procurement Accounts payable Purchase price Mark up	Accounts payable--//→+ Medicine stockout→+Purchase price→+Markup→- Medicine inventory→+ Order procurement rate	Cash flow integration Fluctuating exchange rate between dollar and naira makes it difficult to pay for import medicines and raw materials leading to losses on the

stockout for a period of time, we ensure that we don't have stock out often.” (124/190)	- always available - reorder level	Medicine inventory Order procurement rate		part of manufacturers from government exchange rate policy.

5.2.5.2 Case D conceptual model saturation

The new variable groups of interviews for Case D quotation interpretation were IS04, MM39, MD40, and IS08, while the validation saturation group included IS10, IS16, and IS34. The cumulative variables for each participant were identified and recorded for group one and rearranged in ascending order. From the second group of interviews, IS10 was analysed, and variables were compared to the first group to identify new variables. A new variable was identified and the cumulative value was plotted on a graph (Figure 5.23). IS16 and IS34 had zero percent variables with saturation points before IS16. The causal link, casual loops, and time delay saturation were achieved before IS16 (see Figure 5.24, 5.25, and 5.26, respectively).

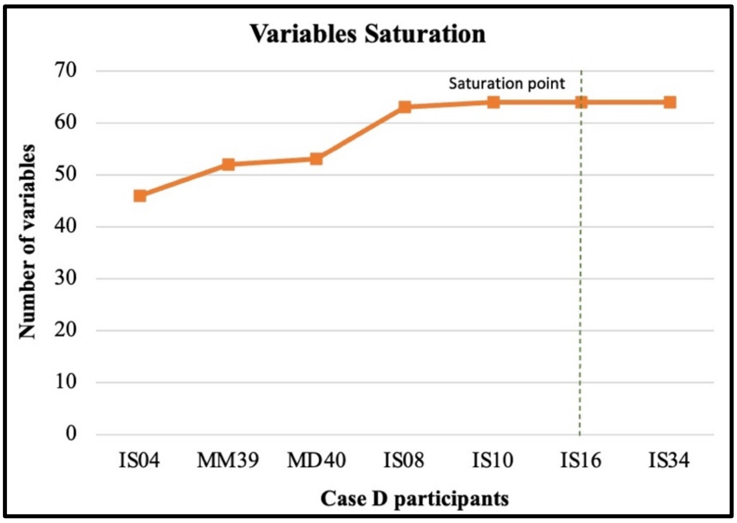


Figure 5.23: Case D conceptual model variable saturation

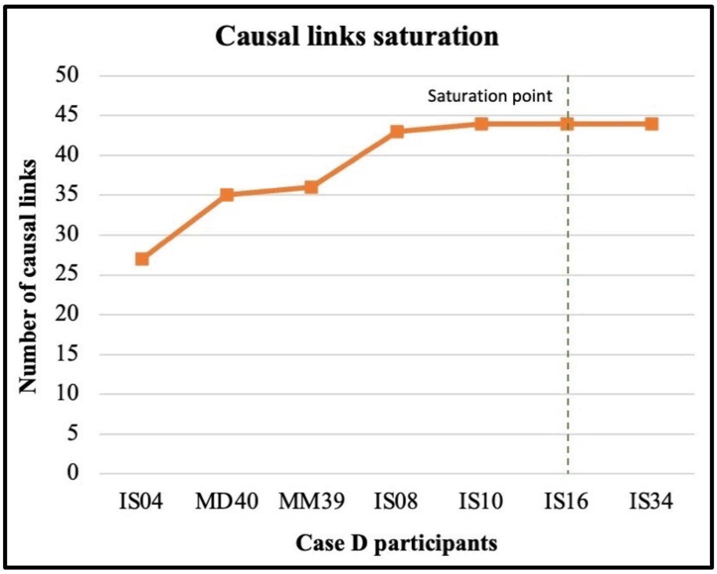


Figure 5.24: Case D conceptual model causal links saturation

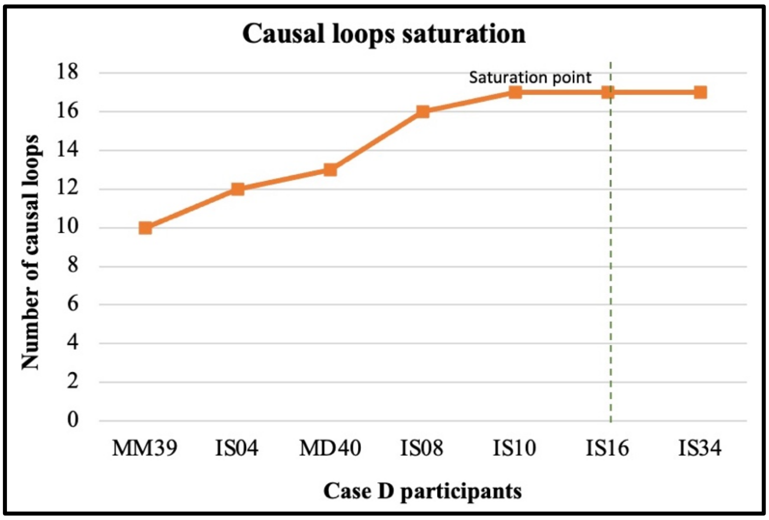


Figure 5.25: Case D conceptual model causal loops saturation

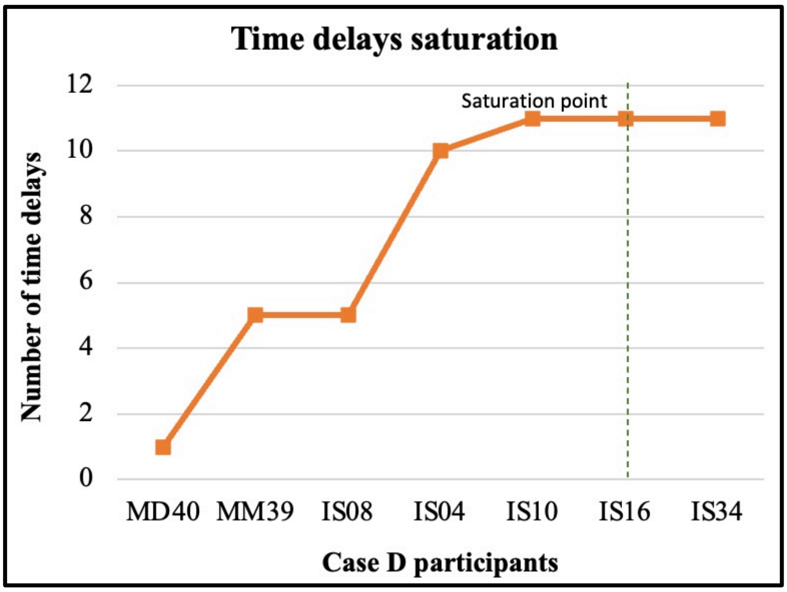


Figure 5.26: Case D conceptual model time delays saturation

5.2.6 Case E mental model of medicine availability

Inadequate process integration and feelings of frustration by staff seeking openness to operate the revolving fund lead to stockouts. The feeling of frustration in waiting for order procurement, as shown in figure 5.27, leads to pressure to integrate strategically with suppliers. The pressure to reduce wait times using technology is fraught with challenges, as observed by IS09.

"…technology…is the way to go. … it can make things to make things easier. But there are challenges that are associated with that…because the network was very poor… it will impact on going digital...". (IS09-10) (Abdulkadir *et al.,* 2023)

Even though the staff work hard to make medicines available to patients, stockouts prevent customer satisfaction, as explained by IS09.

"When a patient comes to the hospital, … making drugs readily available for them is uppermost in our mind ... so we make sure that drugs are always readily available for our patients, when they come to the pharmacy, which keeps them happy. A lot of times, when patients come and they're told that certain drugs are not available, they are not always happy. …we always have this consciousness, we are always working hard to make sure that drugs are available because that is what pleases our customers, our patients." (IS09-04) (Abdulkadir *et al.,* 2023)

"…we can make it better by making sure that suppliers …paid even more promptly. Now, I know that we're trying but it can be better. … the processes involved in getting the payment done, everybody that's involved in that chain, should take up their responsibility and do it as quickly as possible." (IS09-05) (Abdulkadir *et al.,* 2023)

The process of paying suppliers delays medical delivery. The above statement shows the process fragmentation between the pharmacy and accounts departments. Delays in paying suppliers prevent them from fulfilling orders from the hospital. Alignment of processes will get suppliers paid at the right time. Sending patients to get medicines outside the hospital exposes them to the risk of fake medicines and loss of confidence in the hospital. Pharmacists feel helpless when medicines are stocked out, leading to low productivity, as reiterated by IS23:

"If there is internet connectivity, it is easier, you don't have to stand up from your workspace and go to the account to process the payment. And the store people don't need to write out of stock to us with the hard copy…. from our computer, we'll be able to assess out of stock and then process for the new. …if there are consistent computer systems, communication, internet connection and availability." (IS23-02)

Lack of Internet connectivity and computers heightens feelings of frustration among the staff. Having pre-qualified suppliers reduces the constant need for a local purchase order which is cumbersome and delays procurement. Building partnerships with strategic suppliers and contract management improves medicine supply. Infrastructural deficits in the power supply affect operations, and the solar energy provided is inadequate. Introducing electronic prescriptions is defined by a lack of technology and power supply. Tensions around the Treasury Single Account and DRF lead to poor credit scores of the hospitals, and suppliers are reluctant to supply medicines, leading to a fill rate of 60%.

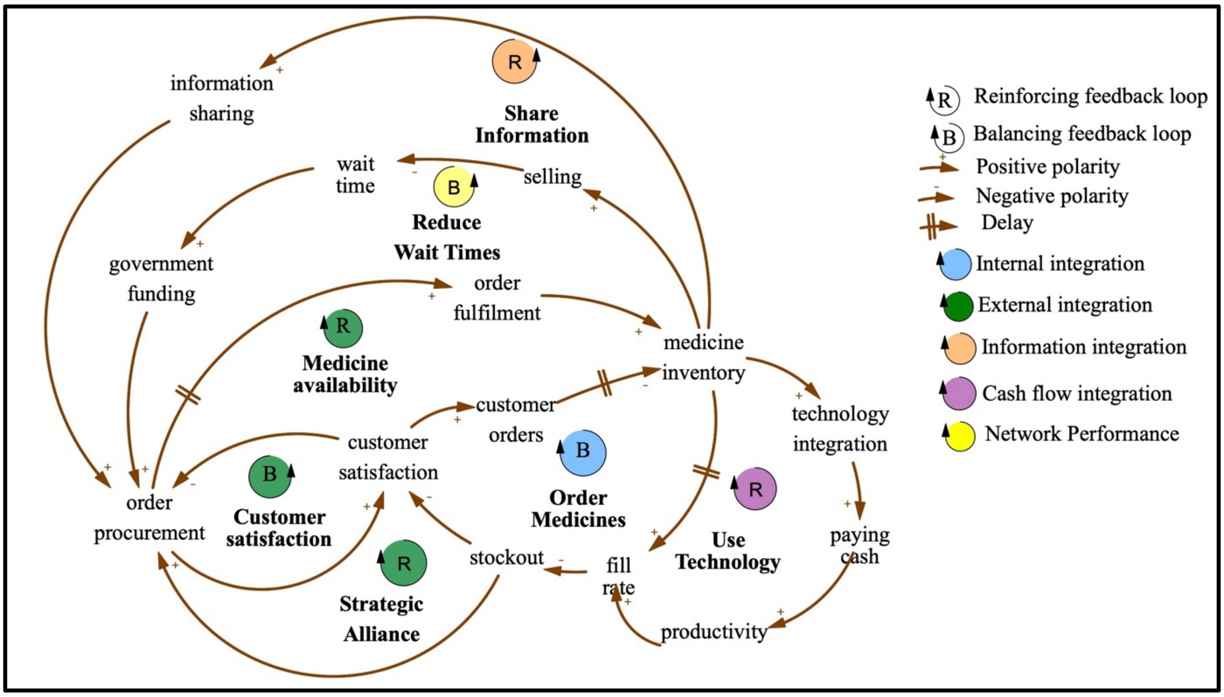


Figure 5.27: Integrated supply chain mental model for Case E participants

Analysing the causes of stockouts across variables in Case E shows some similarities across participants in information sharing, fill rate, and order procurement. Differences varied across participants, with IS09 and IS23 identifying staff productivity and paying cash, respectively, as variables leading to stockouts (Table 5.13).

Table 5.13: Analysis of variables leading to medicine stockout within Case E

Variables causing stockout in Case E	IS09	IS23	IS24	IS25
Technology integration	√	√	-	-
Paying cash	-	√	-	-
Information sharing	√	√	√	√
Wait time	-	√	√	√
Fill rate	√	√	√	√
Order procurement	√	√	√	√
Productivity	√	-	-	-
Customer satisfaction	√	-	√	√
Order fulfilment	-	√	√	√
Selling	-	√	√	√
Government funding	-	√	√	-

5.2.6.1 Causal interpretation and analysis of quotations in Case E

The government funds hospitals at the initiation of the DRF programme. Subsequently, as the funds begin to grow and patients are getting their medicines, stockouts decrease. When the government perceives that hospitals have sufficient funds for continuous replenishment, the allocation of funds decreases, leading to a further reduction in government funding which leads to stockout as patient demand increases (Figure 5.28). IS23 explains how decreasing fund allocation leads to stockouts (see Table 5.14). The increase allocation loop attempts to balance stockouts from decreased government funding. However, the government may stop funding, believing that the hospital has enough cash to revolve and grow the program. IS23 believes the fund has grown but the hospitals cannot afford all medicines "not every drug that we have due to paucity of fund". Allowing funds to grow improves medicine availability, but stockout increases without continuous funding, leading to pressure and calls for increased funding. Poor inventory management practices that lead to shrinkage deplete revolving funds. Improving the capacity of staff reduces shrinkage through technology integration as hospitals seek for "more hands" to help in inventory management and dispensing. The hospital introduced electronic prescriptions, but poor power supply prevented access.

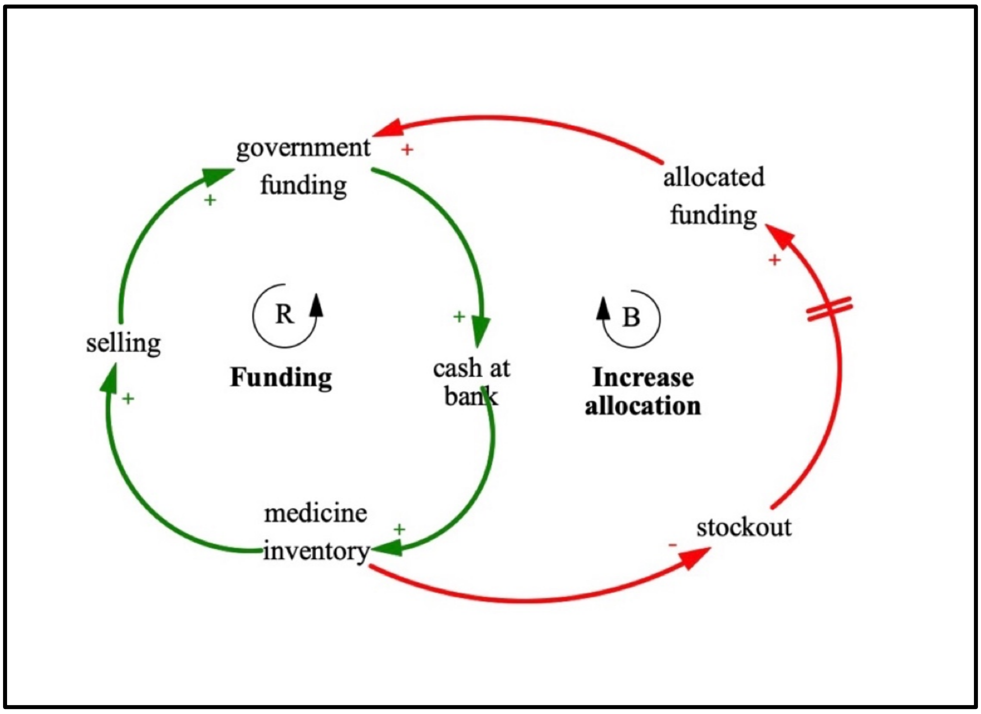


Figure 5.28: Funding and increasing allocation loop in Case E

IS24 explains that the patients pay for the delay in paying suppliers by the hike in prices, which reduces customer satisfaction, but they have no choice if they want to be treated at the hospital.

"…we have to work together, …there needs to be teamwork, all these departments, they have to be proactive, because we all need each other. …one department is not proactive, it affects the other, so we all need to sit-up, do the right thing at the right time, so it will not affect the patient….the suppliers, because when they are not paid at the right time, they are not happy, ... even this framework you are talking about engaging them, they will not be happy, because they know you will tie their money down, you are not going to pay them on time, so they will not be able, they will not want to supply, and when they want to supply, they will put extra money, and the drugs will be higher, for the patient, they will now be complaining, and even …they are buying the drugs, they are not happy." (IS25-12)

When medicines are expensive and patients are dissatisfied, demand will decrease as they try to obtain alternatives, and this situation exposes them to substandard medicines in open markets. See Appendix XIII for Case E interview analysis.

Table 5.14: Evidence of allocated funding cuts on medicine availability

ParticipantNumber-Quote number) "… variables in Phrase(s)" (word count in variables/total word count in causal statement)	**Phrase(s) from participant quote denoting model variables**	**Interpreted model variables**	**Causal link between model variables (→=causal link, --||→=causal link with delay, +/- =positive or negative polarity)**	**Themes from participant quotes**
IS23-07) "we have what is called the drug revolving fund which is a seed money given to hospitals to provide drugs. For the past 20 years government has not provided any money to DRF. we have been using the seed money we had then to revolve, and it has generated a lot of money because at the end of the year, sometimes we have more than 50 million…. we use it for drug revolving fund. If government can fund the hospitals especially the drug aspect, it will really improve because it's not every drug that we have due to paucity of fund". (101/116)	- seed money - drugs - not provided any money - revolve - generated a lot of money - end of the year - not every drug	Government funding Medicine inventory Allocated funding Selling Cash at bank Delay Stockout	Government funding→+Medicine inventory→+ Selling→+ Cash at bank--//→- Allocated funding→+ Stockout	Cash flow integration Allowing the funds to grow improves medicine availability but stockout increases without continuous funding.

5.2.6.2 Case E conceptual model saturation

The new variable group of interviews for Case E quotation interpretation was IS09, IS25, IS24, and IS23, whereas the validation saturation group included IS26, MM54, and IS29. The cumulative variables for each participant were identified and recorded for group one and rearranged in ascending order. From the second group of interviews, IS26 was analysed, and variables were compared to the first group to identify new variables. Five new variables were identified and the cumulative values were plotted on a graph (Figure 5.29). MM54 and IS29 had zero percent variables with saturation points before IS19. The causal link, causal loops, and time delay saturation were achieved before IS16 (see Figure 5.30, 5.31, and 5.32, respectively).

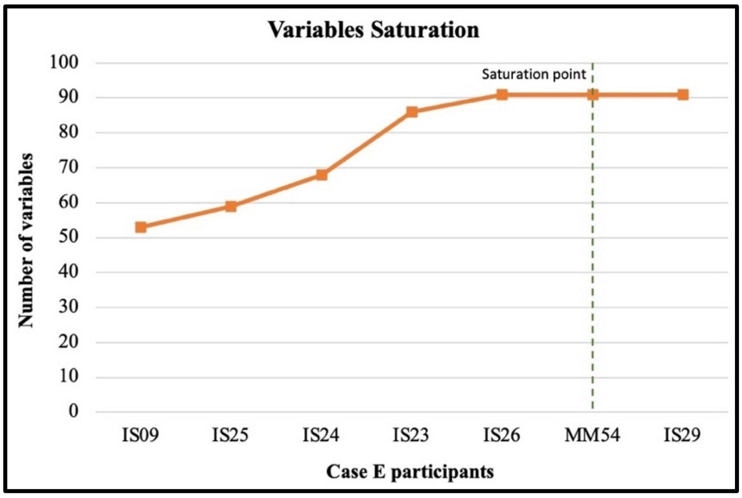


Figure 5.29: Case E conceptual model variable saturation

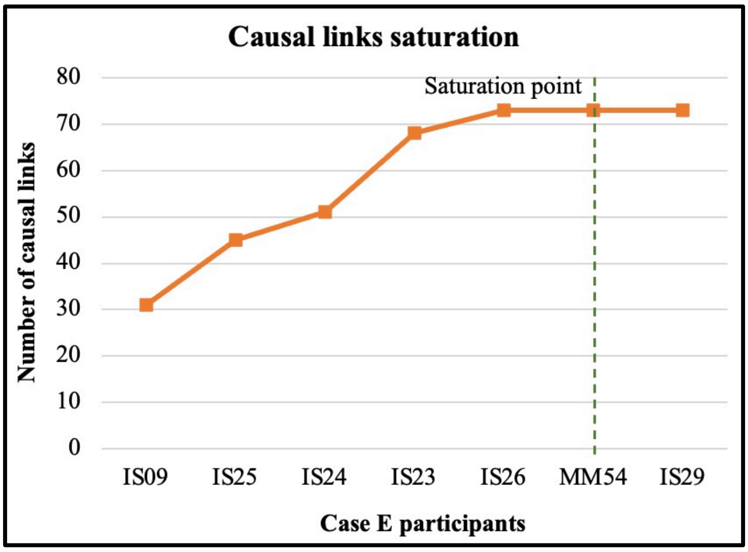


Figure 5.30: Case E conceptual model causal links saturation

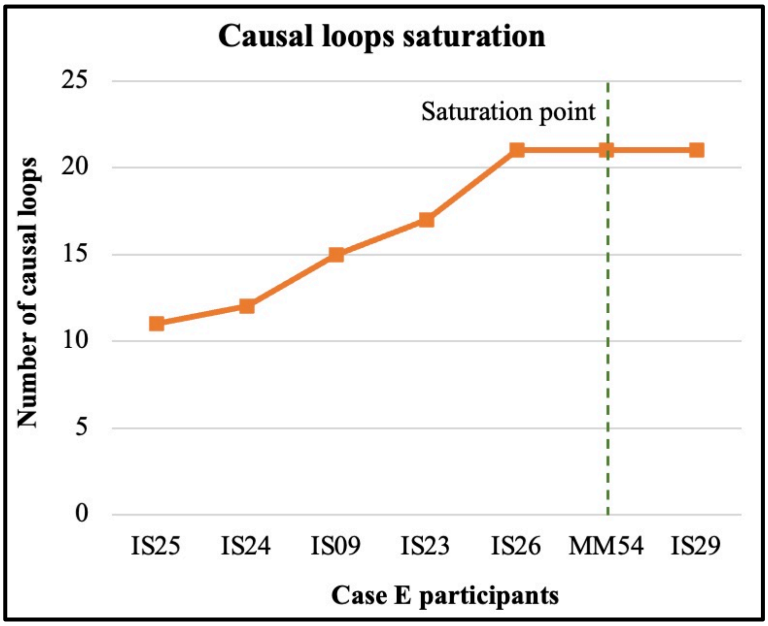


Figure 5.31: Case E conceptual model causal loops saturation

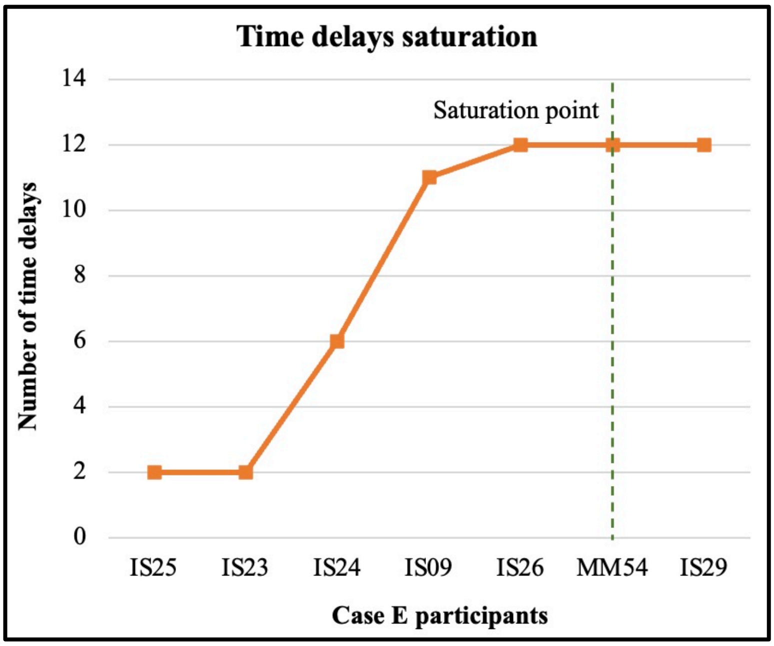


Figure 5.32: Case E conceptual model time delays saturation

5.2.7 Cross-case mental model and dynamic hypothesis

Five case mental models were combined and pruned to develop a cross-case mental model. The cross-case analysis of the mental models showed that all hospitals had a significant stockout of essential medicines. Information sharing and maintaining on the shelf medicine inventory were identified as variables affecting the fill rate with a 100% score. A score of 100% was attained when all participants identified the variable as causal to medicine availability. The next category of variables includes visibility, selling, and paying suppliers of medicines to customers, with a score range of 61-70%. Followed by 41-60% including supply delay, hospital-supplier relationship (trust), cash at bank, order fulfilment, and customer satisfaction. Stakeholder trust and government funding with a score range of 21-40% precedes medicine production which has the lowest implication in causing medicine stockout at 1-20%. Financial management, as a common challenge across hospitals, agrees with the survey output and shows specific variables and dynamic behaviours leading to order fulfilment. Selling, cash at the bank, and paying suppliers, as part of the cash flow loop, increase the fill rate and customer satisfaction (Table 5.15). The three balancing loops of increasing production and on-shelf medicine availability were followed by reducing supply delays, improving MFR, and improving customer satisfaction (Figure 5.33). Fluctuating dollar exchange rate encourages opportunism and raw material suppliers increase their prices to make more profit. When prices increase, selling of products decrease leading to decrease in production and manufacturers staff motivation also decreases as noted by MM47:

“Naturally, the importers, raw supply providers, I feel there should be like a set goal of understanding because [of] the economy of the country …, by this quarter we will pay you and these are the materials we will need, even without change in dollar, because change in dollar affect a lot of things and once there’s a change, the supplier might be greedy …. You know business is about profit, it’s not about friendship or family. So everybody want to maximize every way they can make profit, so if there’s an agreement that okay, this are the things we want and these are the payment upfront, … it will help a lot, so that the economic situation won’t affect the productivity of the company.” (MM47-07)

MM47 identifies insecurity and difficult terrain as being responsible for supply delays from suppliers.

“Logistics is the number one, because of the terrain where we work .... Once insecurity issues and the likes, if logistics can be properly handled, I feel it will put us back in our games like fast delivery.” (MM47-06).

Improving production and delivery increases the shelf availability of medicines, leading to increased fill rates.

Table 5.15: Cross-case dynamic variables identified by case study participants

Dynamic Hypothesis Variables	Case A count	Case B count	Case C count	Case D count	Case E count	Total variables count	Cross-case percentage (%)
Order fulfilment	1	2	2	3	3	11	55
Hospital-supplier relationship (trust)	4	2	4	1	1	12	60
Customer satisfaction	2	2	1	1	3	9	45
Paying suppliers	1	3	3	3	3	13	65
Medicine production	2	1	0	1	0	4	20
Visibility	4	2	3	3	2	14	70
Government funding	1	1	1	2	2	7	35
Supply delay	2	4	1	1	1	9	45
Information sharing	4	4	4	4	4	20	100
Cash at bank	1	2	3	0	3	9	45
Hospital-stakeholder relationship (trust)	1	1	2	2	2	8	40
Selling	3	3	3	2	3	14	70
Fill rate	3	4	3	3	4	17	85
Medicine inventory	4	4	4	4	4	20	100

The cross-case variables show the level of concurrence and differences between causal variables across cases, as shown in Figure 5.33. This dynamic theory is a micro-theory of SCI that is used to build an integrated distribution model (Sterman, 2000) for simulating DRF SCs. The simulation results are presented in chapter six.

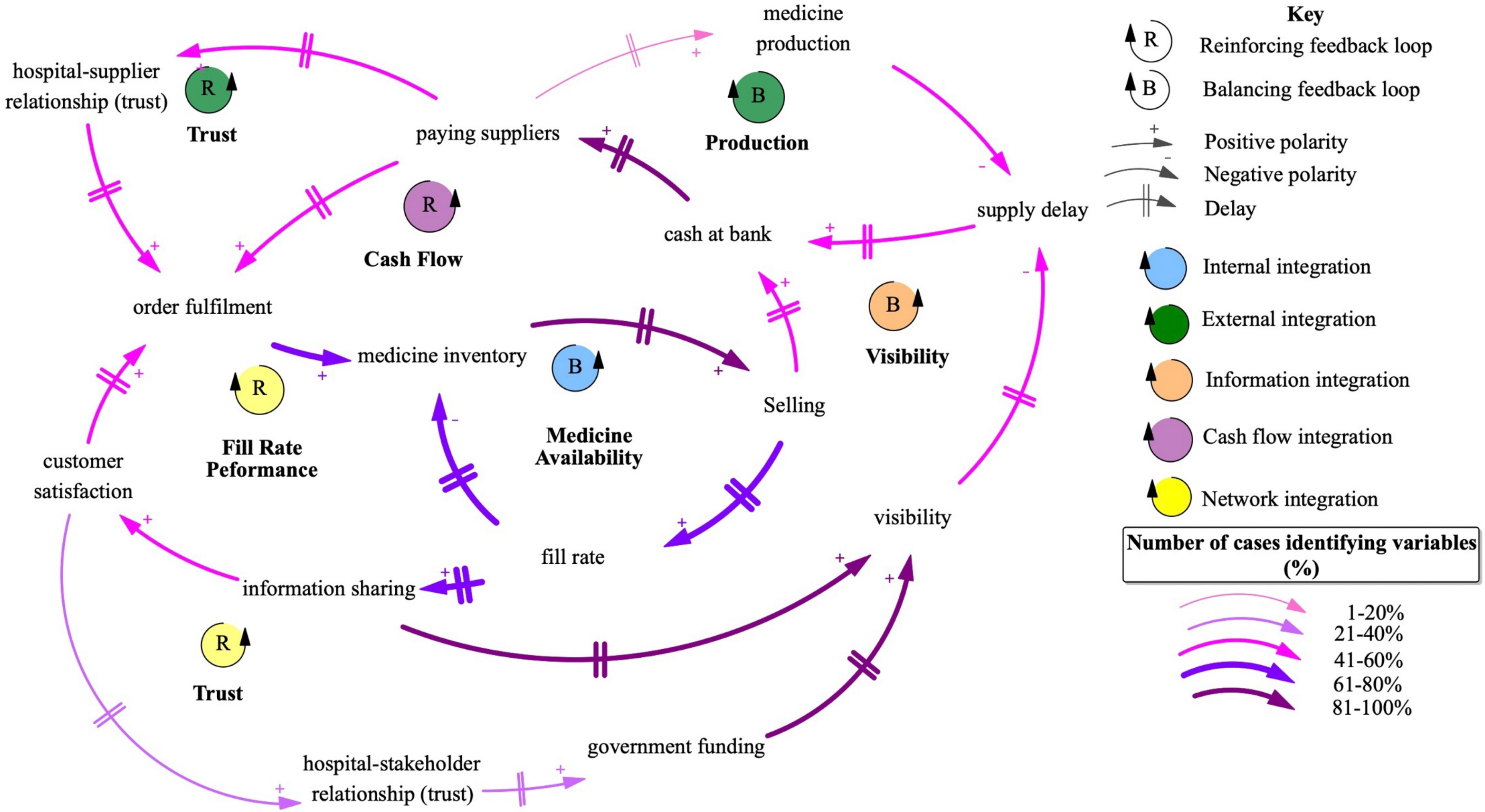


Figure 5.33: A cross-case dynamic theory for supply chain network integration

Time delays within the supply chain occur at the internal and external levels. Operational activities such as forecasting, quantification, and sourcing require working between different teams in the hospital to provide medicines to patients. The multidisciplinary nature of healthcare SCs necessitates the movement of products and information at various levels. Participants observed delays in internal operations and procurement with external suppliers. Delays from fulfilling customer demands and stakeholder expectations were also captured in the mental models of three participants, SP43, IS08, and MM39, explicitly identifying the effects of stakeholder delays on the provision of medicines. SP43-07 mentions “most of the time” to describe the mode of engaging stakeholders using the responsible, accountable, consulted, and informed matrix for project management. The delay perception of “at the point of” explains what happens when engagement does not give “the percentages” of the medicine fill rate. IS08-13 describes “still waiting” as a delay in waiting for government funding to implement digitalisation of the DRF and believes that removing the “bottleneck” will improve the MFR in the SC. MM39-08 perceives that some government importation policies prevent medicine availability at the right time “when due” and these policies lead to medicine stockout for “a period” leading to loss of profits for the manufacturer and increased price of medicines for the customers (Table 5.16).

Table 5.16: Time delays affecting operations in an integrated supply chain network

Participants quote number	Interpretation of time delays	Levels of time delay			
		Internal operations	External supplier	External customer	External stakeholders
IS01-03	-we don't share data -communication with the patients are minimal	x	x	X	-
IS03-06	-at a certain time -one thing and then the next	x	x	-	-
MM45-09	- review periodically - any point in time	x	-	X	-
SP43-07	- most of the time - at the point of	x	-	-	x
IS05-01	- when due - to delay	x	x	-	-
IS05-10	- a delay - at the end of the day - for a very long time	x	x	-	-
IS07-02	- after specified period of time - not delay - delay in their payment	x	x	-	-
IS07-12	- take much time - take a long time - when due	x	x	-	-
IS22-12	- doesn't have to go - going to and from	x	-	x	-
MM47-05	- as soon as possible - delay in supply	x	x	x	-
IS02-03	- within a certain time	x	x	-	-

	- maybe one week or two weeks				
IS02-06	- before sending it to us - wasted time	x	x	-	-
IS11-06	- in recent times - work around the clock	x	-	-	-
IS11-10	- payment delay - get their money on time -two months to one year	x	x	-	-
IS20-02	-more than a month, two, three, four months -within two weeks latest	x	x	-	-
IS04-03	- reduce lead times - on time - timely submission -there should be prompt	x	x	-	-
IS04-08	- faster - takes a length of time - not finish on time	x	x	-	-
IS08-02	- much faster - three to four months	x	x	-	-
IS08-03	- end of the quarter - until the next quarter	x	x	-	-
IS08-13	- still waiting - bottleneck	x	-	-	x

MM39-02	-goes from one organization to the other - when due	x	x	-	-
MM39-08	- when due - for a period of time	-	x	-	x
IS09-02	- can affect how often - have to wait	-	-	-	-
IS09-13	- as quickly as possible - come on time - should do it promptly	x	x	-	-
IS09-14	-acted upon immediately - as soon as possible	-	x	x	-
IS23-05	- most of the time - it delays	x	-	x	-
IS23-06	-reduce the out of stock and time - it takes time	x	x	-	-
IS24-02	- save time - shorten the lead time -shorten the patient waiting	x	x	x	-
IS24-03	- delays -shorten the patient waiting time	x	-	x	-
IS25-03	- very long time - delay again -doesn't come immediately	x	x	x	-

Analysing time delays across cases shows that Case B identified the highest number of delays with 27%, followed by Case C (23%), Case A had 19%, Case D (17%), and Case E had the lowest count of 14% (Table 5.17). Paying suppliers and medicine inventories had the highest percentage of time delays across all cases (100%). Government funding and the hospital-stakeholder relationship (trust) had the lowest value of 20%. The low perception of time delays in increasing stakeholder trust among system operators prevents adequate funding from the government and donors in a reinforcing loop (Figure 5.34).

Table 5.17: Dynamic hypothesis variables and time delays across cases

Dynamic hypothesis variables	Case A time delays	Case B time delays	Case C time delays	Case D time delays	Case E time delays	Number of cases identifying	Percentage of cases identifying (%)
Order fulfilment	0	0	2	3	1	3	60
Hospital-supplier relationship (trust)	1	4	2	0	1	4	80
Customer satisfaction	0	0	0	0	0	0	0
Paying suppliers	1	3	1	2	1	5	100
Medicine production	1	1	0	1	0	3	60
Visibility	1	1	0	0	0	2	40
Government funding	0	0	0	0	1	1	20
Supply delay	0	1	1	0	1	3	60
Information sharing	2	1	6	3	0	4	80
Cash at bank	0	0	1	2	0	2	40
Hospital-stakeholder relationship (trust)	0	0	1	0	0	1	20
Selling	1	1	0	0	0	2	40
Fill rate	2	2	0	0	5	3	60
Medicine inventory	6	7	4	2	1	5	100
Total number of delays	15	21	18	13	11	78	-
Percentage of delays identified (%)	19	27	23	17	14	-	-

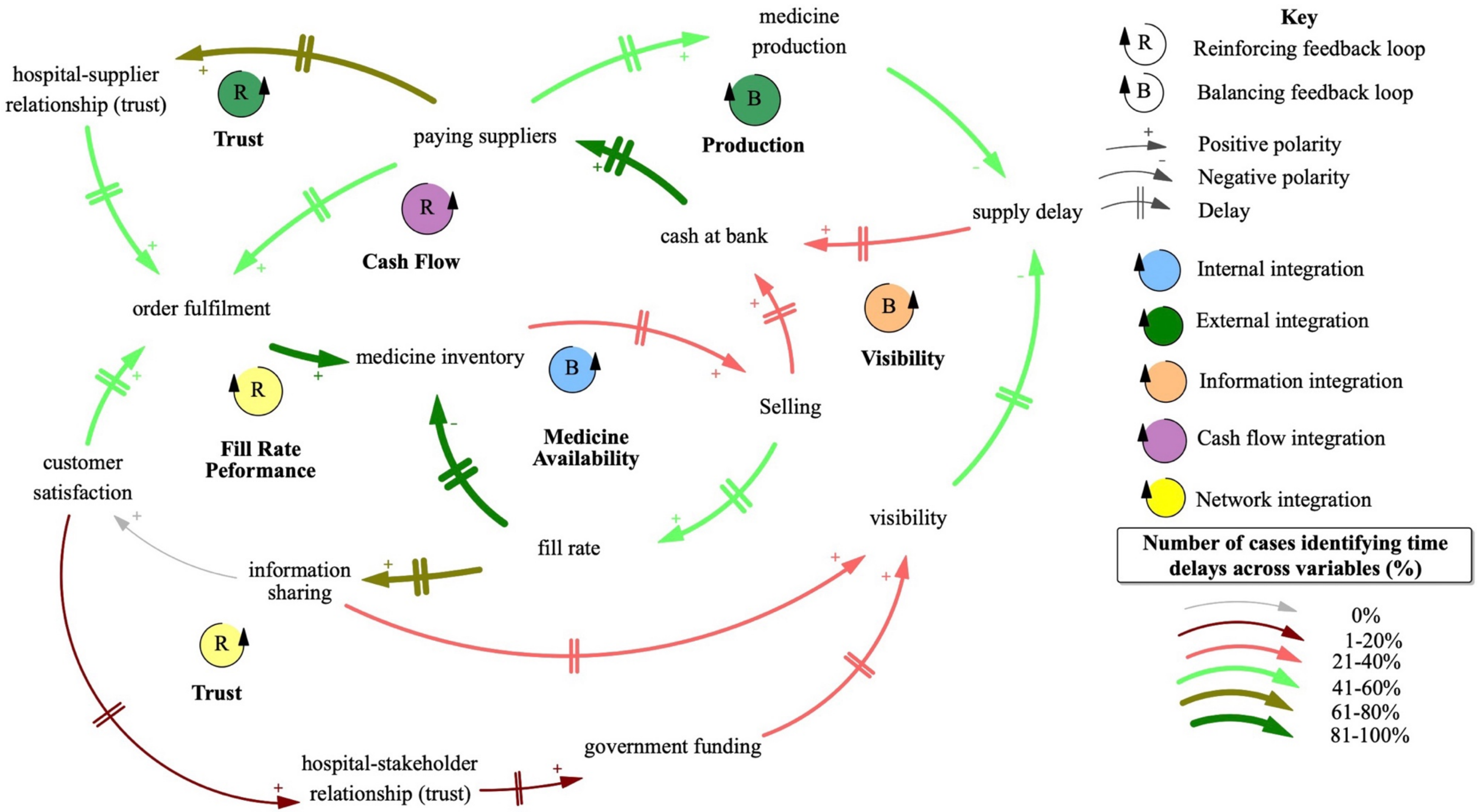


Figure 5.34: Network integration dynamic theory with time delays across cases

5.2.7.1 Supply chain integration causal statements

Determining the contribution of each case study towards supply chain integration aggregates causal information from case study participants to various levels of integration (Kim, 2009). The y-axis represents the total word count for each causal statement and the x-axis represents the number of causal statements per case. Case A shows internal integration with the highest causal word count of 230, and customer integration with the lowest count of 109 (Figure 5.35).

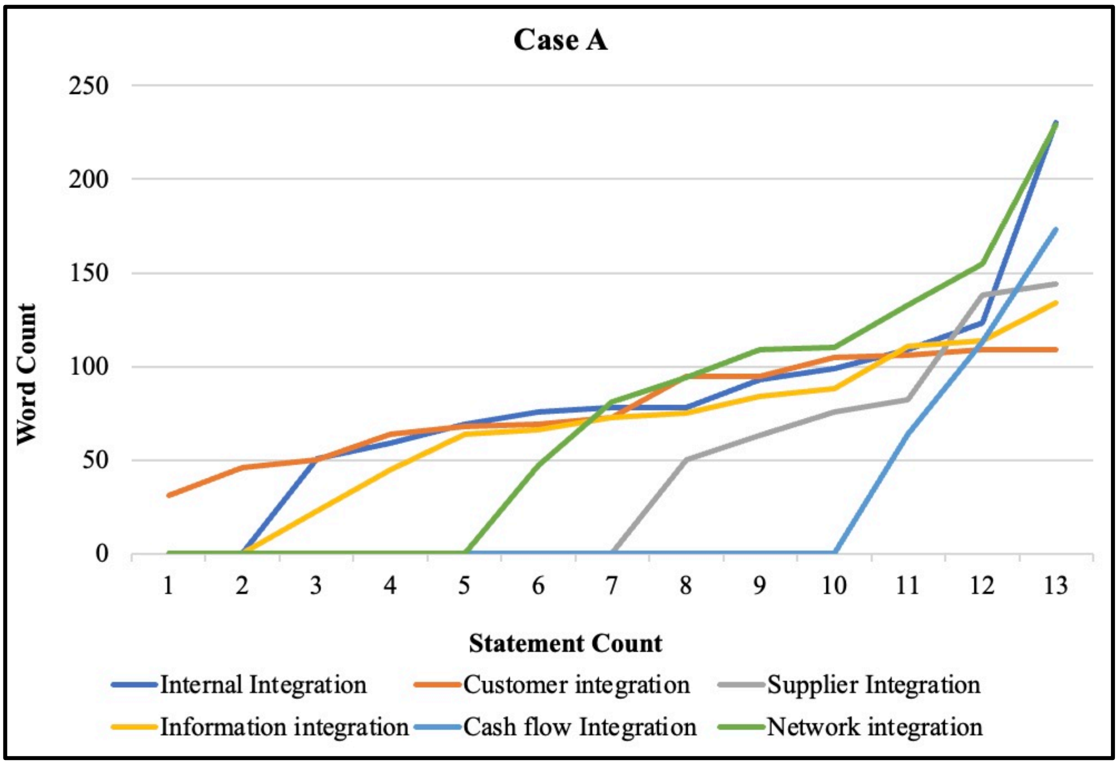


Figure 5.35: Participants causal statements for Case A supply chain integration

Case B shows that the supplier integration causal statement had the highest word count of 192 and network integration had the lowest 106 counts (Figure 5.36).

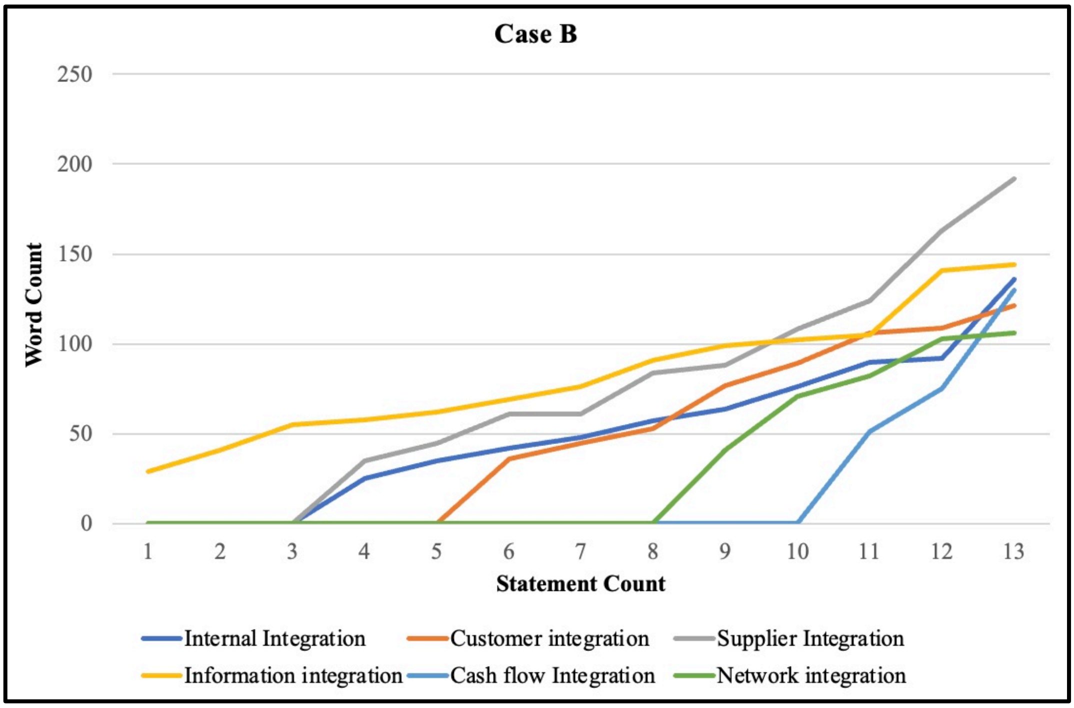


Figure 5.36: Participants causal statements for Case B supply chain integration

The network integration causal statement had the highest word count of 200, and internal integration had the lowest, with 99 counts (Figure 5.37).

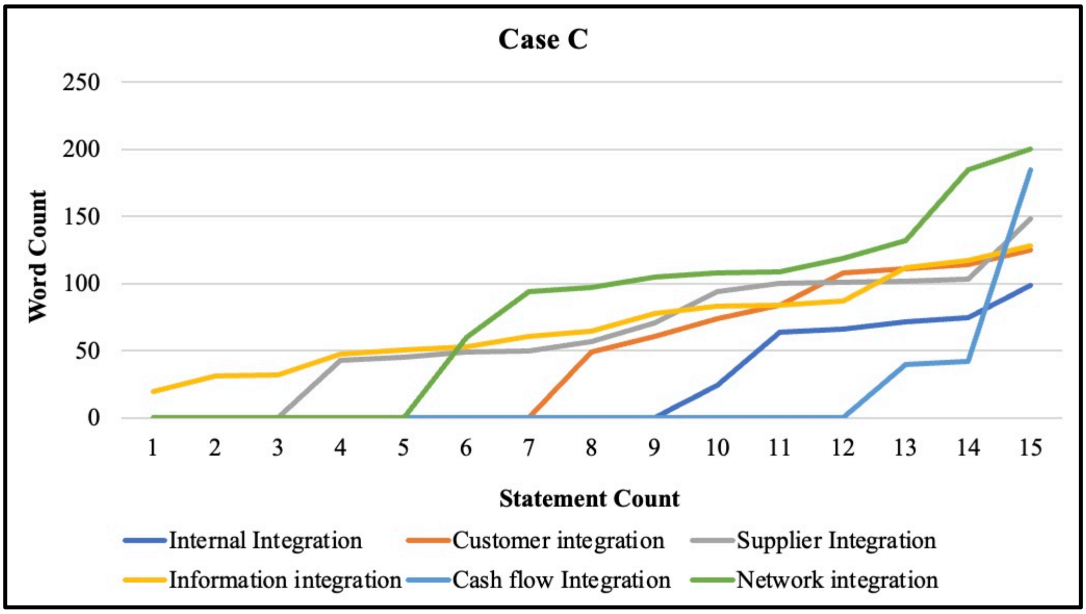


Figure 5.37: Participants causal statements for Case C supply chain integration

The internal integration causal statement had the highest word count of 191 and network integration had the lowest count of 87 in Case D (Figure 5.38).

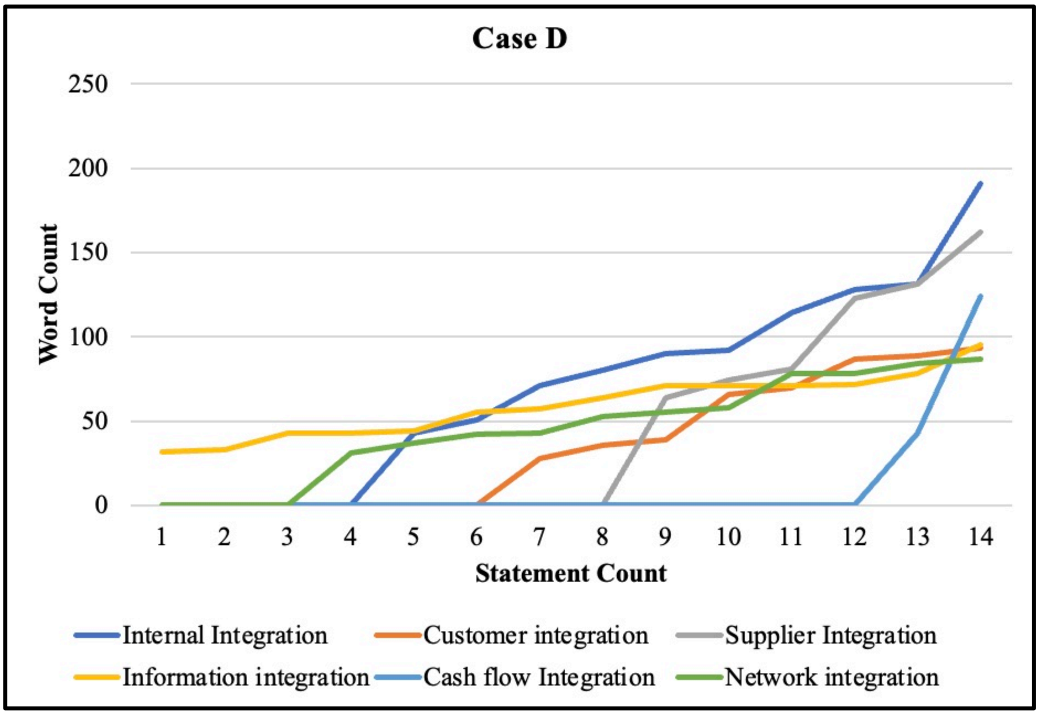


Figure 5.38: Participants causal statements for Case D supply chain integration

Customer integration had the highest word count of 256 and cash flow integration had the lowest count of 101 (Figure 5.39).

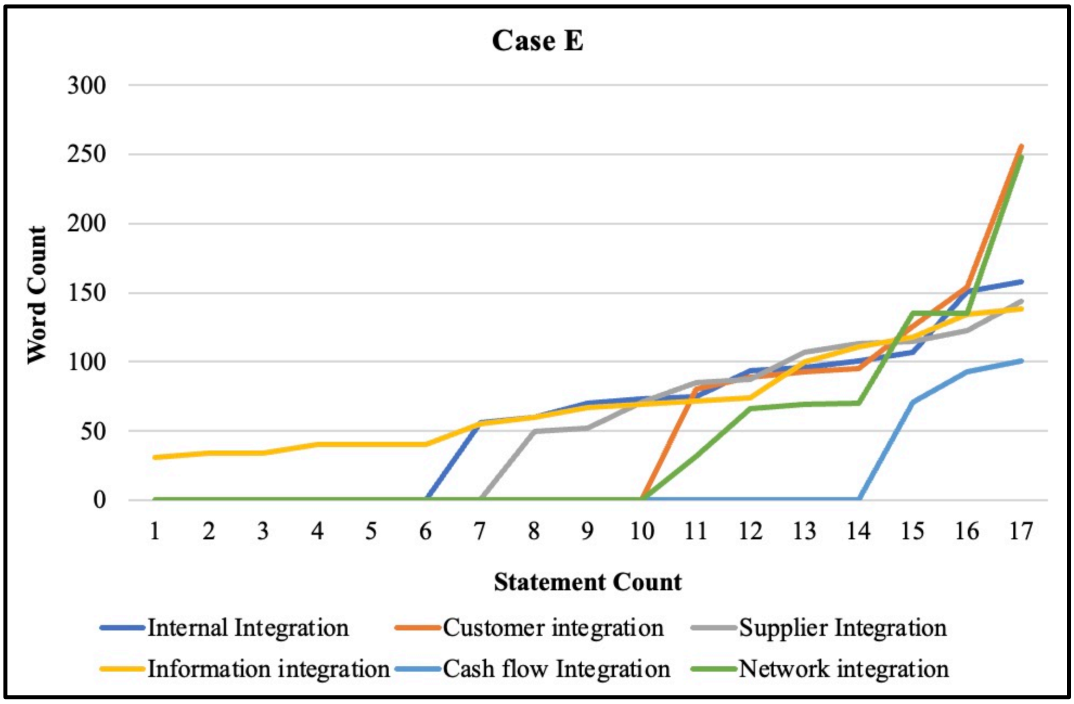


Figure 5.39: Participants causal statements for Case E supply chain integration

Cases A and D are similar in having the highest count for internal integration, whereas Case B and Case D share similarity in having the lowest count for network integration. Case E had customer integration as the highest count, whereas Case A had customer integration as the lowest count. Only Case E had cash flow integration as the lowest count. The distribution of SCI themes across the case study participants shows that information integration had the highest causal themes and cash flow integration had the lowest count. The case study participants perceived delays and feedback from information sharing and information integration, as evidenced by the details provided about operating the SCs. In contrast, cash flow integration had the fewest statements on causality which could be due to the inadequate understanding of the SC structures, delays, and feedback responsible for cash flow integration. Fifty percent of participants had no idea about the reasons for delays in paying suppliers, while 35 percent of participants had little information on cash flow delays and feedback. Only 15 percent of participants provided medium information on the causality of cash flow problems (Table 5.18). Case E had the highest causal themes at 55, whereas Case B had the lowest, with 49 themes (Table 5.19). Information integration had the highest count across all cases, as participants identified causality between information-sharing and MFR.

Table 5.18: Distribution of supply chain integration themes across case study participants

Case study participants	Internal integration	Customer integration	Supplier integration	Information integration	Cash flow integration	Network integration	Total count
IS01	2	4	2	2	0	2	12
IS03	3	2	1	2	3	5	16
MM45	3	3	2	3	0	0	11
SP43	3	4	1	4	0	2	14
IS05	2	1	4	1	1	1	10
IS07	3	2	2	3	1	2	13
IS22	2	3	2	3	1	2	13
MM47	2	2	2	6	0	0	12
IS02	2	2	4	6	0	2	16
IS11	1	4	4	3	1	5	18
IS20	1	1	3	3	1	2	11
IS21	2	1	1	3	1	1	9
IS04	3	2	0	4	0	3	12
IS08	3	2	4	2	0	5	16
MD40	2	4	0	5	0	2	13
MM39	2	0	2	3	2	1	10
IS09	4	1	3	5	0	2	15

IS23	4	0	5	4	2	2	17
IS24	1	2	2	5	0	2	12
IS25	3	3	1	2	1	1	11
Total count	48	43	45	69	14	42	261

Key	**Max**	**High**	**Medium**	**Low**	**Zero**
	100%	75%	50%	25%	0%

Table 5.19: Distribution of supply chain integration themes across cases

Case study organisation	**Internal Integration**	**Customer integration**	**Supplier Integration**	**Information integration**	**Cash flow Integration**	**Network integration**	**Total count**
Case A	11	13	6	11	3	9	53
Case B	9	8	10	13	3	5	48
Case C	6	8	12	15	3	10	54
Case D	10	8	6	14	2	11	51
Case E	12	6	11	16	3	7	55
Total count	48	43	45	69	14	42	261

5.3 Vensim software for modelling and simulation

This thesis uses the Vensim software to build and simulate an integrated essential medicine supply chain model. The software is easy to use and has a user-friendly interface. Vensim PLE Plus was used throughout this study to build and simulate the model. The software user interface consists of a title bar, main toolbar, sketch tools, analysis tools, navigation tools, and appearance tools (Figure 5.40).

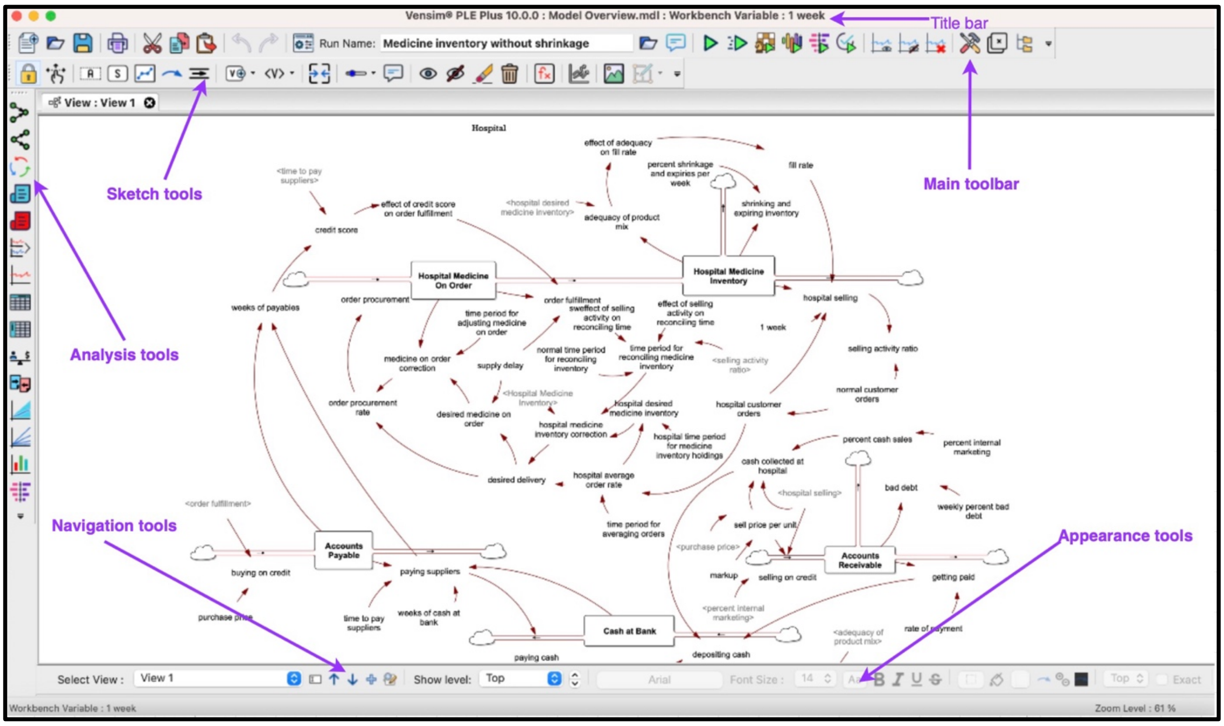


Figure 5.40: Vensim PLE Plus software user interface

The sketch tools contained toolsets for selecting and imputing variables and stocks to build the model (Figure 5.41).

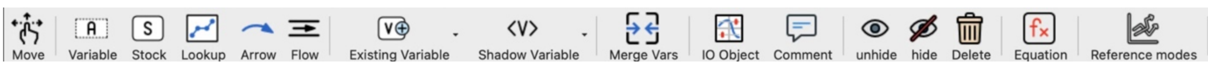
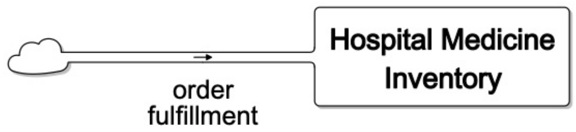


Figure 5.41: Vensim sketch tool bar

For example, to build a stock and flow diagram of the hospital medicine inventory (Figure 5.42), start by selecting the **Stock** button, place it on a blank page, and click to enter the name of the stock. Click enter to save the stock names. To create a flow of order fulfilment in the stock, select the **Variable** button and click on a blank space before the **Stock**, drag and drop the flow arrow in the stock box, and type the name of the variable before clicking the enter. To input the value for the stock, click the **Equation** button and enter the initial value in the equation pop-up page. See the model equation for hospital medicine inventory in Figure 5.42, where order fulfilment is the inflow at time step *dt*.



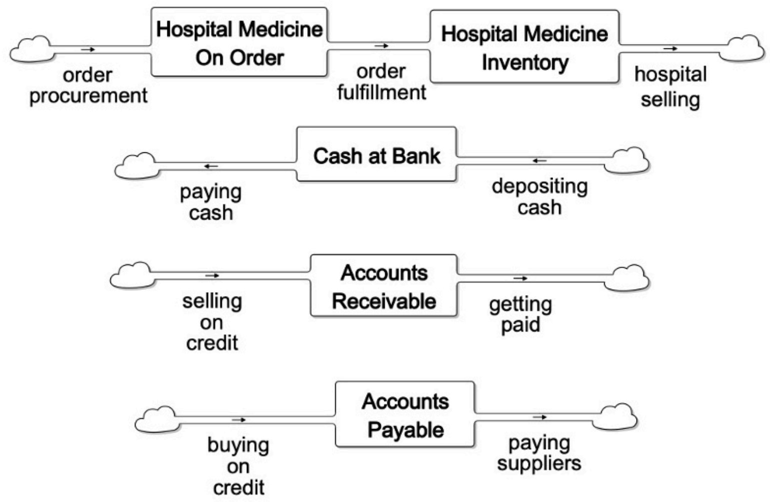
Equation

Hospital Medicine Inventory = $\int$[order fulfilment] *dt* because order fulfilment is the inflow at time step *dt*.

Figure 5.42: Sample stock and flow model equation

5.3.1 Basic model differential equations

The availability of medicine in the DRF SC was modelled based on five stocks at the hospital level. Hospital medicine inventory, medicine on order, cash at bank, accounts receivable, and accounts payable. The accumulated hospital medicine inventory is based on the order-fulfilment rate and selling rate of medicines to customers. Hospital medicine inventory is modelled as stock, while order fulfilment and selling flows into and out of the stock, respectively. The stock of hospital inventory depicts the accumulation of medicines over time which increases when suppliers fulfil orders to the hospital and decreases when medicines are sold to patients. The supply line is represented as hospital medicine on order, showing medicines that have been procured but not yet delivered to the hospital. See figure 5.43 below for the outline of the hospital stock and flow model equations. These formulations assume that there are no delays in order fulfilment, procurement, or depositing cash at the bank for revolving fund SCs. On the other hand, the inventory management model is filled with delays that can arise within the hospital chain in the process of managing product acquisition to delays from medicine suppliers in fulfilling hospital orders.



Hospital medicine inventory = $\int$ [order fulfilment-hospital selling] dt

Hospital medicine on order = $\int$ [order procurement-order fulfilment] dt

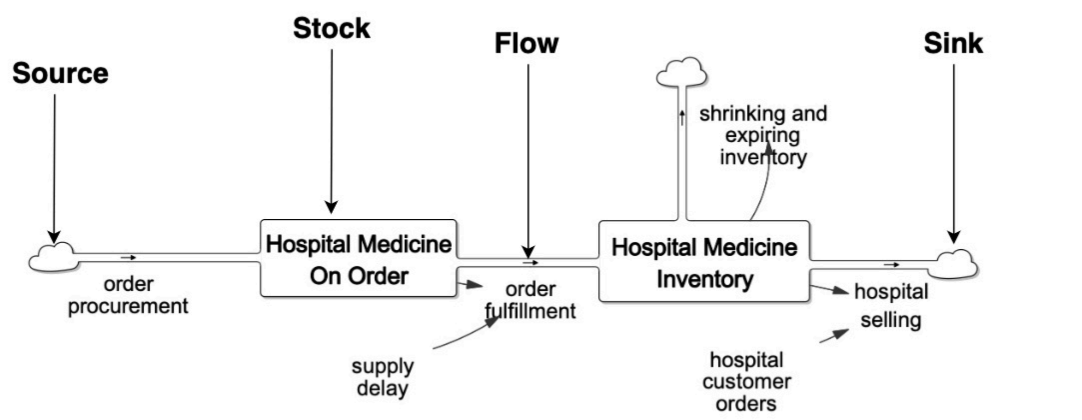
Cash at bank = $\int$ [depositing cash-paying cash] dt

Account receivables = $\int$ [selling on credit-getting paid] dt

Accounts payable = $\int$ [buying on credit-paying suppliers] dt

Figure 5.43: Hospital inventory stock and flow model equations

Accurate modelling of the medicine inventory must capture the delays from the order fulfilment and procurement processes and consider losses from selling medicines to patients, expiries, and pilferages to account for reduction in stock level as shown in the model example below (Figure 5.44) with equations that consider supply delay and lossess from shrinkage and medicine expiries.



Hospital medicine inventory = ∫ [order fulfilment-hospital selling-shrinking and expiring inventory] *dt*

Figure 5.44: Model showing delay to fulfilment and inventory losses

Another source of loss is cash from bad debt, which arises when the pharmacy department sells medicines on credit to other departments in the hospital. When these departments fail to pay back over a long period, they are written off as losses to the revolving fund, but managers do not consider it during decision-making or overall to the DRF. See figure 6.3 in chapter 6 for a more detailed model showing all delays and losses in the DRF model.

5.3 Conclusion

Public healthcare SCs are largely government-owned in Nigeria, and bringing the relevant perspectives of government and non-government stakeholders is necessary for the successful implementation of the DRF program. End-to-end visibility for transparency and accountability to empower hospitals to meet contract obligations increases network performance and the MFR. Visibility also allows partners to sense and respond faster to patients' needs, thereby reducing shrinking and expiring inventories. The five identified integration levels include internal, external, information, cash flow, and network integration. Internal teamwork increases EMs availability by balancing the cash flow reinforcing loop. External integration in the production and trust loop helps increase medicine inventory. Reinforcing cash flow enables production and order fulfilment. Network integration ensures fill rate performance in a reinforcing loop. Network integration and pooling of resources for procurement can reduce the sale price and increase the availability and fill rates. Lack of trust and teamwork among teams could be due to the top-down approach of introducing policies by the government. The introduction of procurement units created tensions in the organisation, as other departments that had been handling procurement of medicines in the past felt relegated to decision-making on the choice of medicines to procure. Management needs to build trust and shared-purpose among all staff. The organisation can benefit from supply chain practices to increase team building, such as improving visibility, transparency, and communication. This finding is in line with studies that argue that top management support is needed for internal integration (Kang and Moon, 2016; Shee *et al.*, 2018) and that internal cohesion is the bedrock of external partnerships. Automation of cash flows from the point of sale to the payment of suppliers reduces delays and can improve trust between suppliers and hospitals, leading to improved deliveries. Digitising SC operations reduces errors and increases the flow of information, medicine, and cash.

Access to lower dollar exchange rates for raw material importation and relationships between local manufacturers and foreign raw material suppliers can be mitigated by engaging in strategic partnerships and exploring win-win negotiation options. The low perception of medicine production as a variable causing stockouts could be due to the lack of awareness of hospital staff regarding the challenges manufacturers face with fluctuating foreign exchange during the importation of raw materials and active pharmaceutical ingredients. Strategic alliances between manufacturers and raw material suppliers, together with government intervention in sourcing dollars for imports, can facilitate a win-win situation for the partners. Government intervention can reduce tax rates and allocate forex (Cravino 2017). Supplier opportunism arises from the asymmetry of information which can be minimised with strategic partnerships and win-win negotiations. Providing a secure and enabling environment for businesses is a governmental function. The use of drone technology for delivery minimises the risk of loss of life, and collaboration among network partners can expand access to drone technology use by pooling deliveries. Aligning a treasury single-account policy with the DRF will minimise tensions in access to funds for procurement. The sources of friction could be the design of the two policies or their implementation. Stakeholder consultation can identify and address areas for improvement. The treasury policy is a digital transformation of cash flow while the legacy DRF is still manually operated in this organisation which could also be the source of tensions observed. Bureaucracy from regulatory agencies during importation of raw materials and manufacturing can be improved by closer working ties and information integration. Transparency and adherence to standard process together with system strengthening by government can fast-track the procedures and processes. Developing staff capacity for demand and supply planning can disrupt the emergency procurement trap and ensure smooth flow of products. Resolving the tensions between donations and DRF policies will minimise shrinkage and expiries to increase fill rate. Contract management and abiding by the guidelines and processes of operations increases suppliers' confidence in the system.

The use of digital warehouse management technology reduces shrinkage by providing visibility and speeding up the processes while minimising human error. Building digital capacity to manage operations will make the staff happy and increase productivity. Ensuring strict adherence to procurement guidelines and audits prevents corrupt practices. Knowledge sharing within the network can help SCs learn best practices from more advanced SCs like Case A to improve their own processes and systems. Building supply chain management capacities in a network will improve MFR and network performance. Some manufacturers in the network have more matured SCs with digital technology use which can be shared with collaboration and strategic partnerships. Building trust with regulatory bodies and process integration to boost production capacity and compliance will ensure order fulfilment to hospitals. Government exchange rate policy must provide access to manufacturers to meet their obligations to raw material suppliers for seamless medicine production. The government can also introduce instruments to encourage local raw material production to reduce the uncertainty from foreign exchange. The cross-case mental dynamic hypothesis is a conceptual network model for SCI. A conceptual model was used to build a simulation model of the SCI and was tested for its effects on the MFR.

6 CASE STUDIES MODELLING AND SIMULATION

6.1 Introduction

The Drug Revolving Fund Model includes financial management and cash flow at the core of providing medicines for patients in hospitals. Medicines and cash move along with information. When medicines are sold, the cash collected is deposited in the bank as cash, which is used to pay suppliers for procured medicines. Medicine that is not used over time is returned to the distributor or manufacturer, depending on the source. The cycle is supposed to be a virtuous circle in which funds increase over time and meet the needs of patients (Figure 6.1). SCs sell medicines on credit to other hospitals or departments known as internal markets. This section introduces the modelling and simulation of the integrated essential medicine SC, together with the testing of policies to improve MFR using the cross-case conceptual model. Because Case A is the only SC that measures end-to-end SC performance from the maturity model output, the integrated model was developed with data from Case A and tested on Cases A, B, C, D, and E. Participants from other cases were engaged in stakeholder consultations and used the model for learning and comparisons with their operations. The simulation model from Case A served as the reference model for other hospitals. Case A had the highest number of service delivery points (1088), which covers 98% of the state and serves as a good representative case for the network. Case A comprises primary, secondary, and tertiary levels of care and has a higher number of relationships with customers, manufacturers, distributors, donors, and CSOs, making it a good candidate for the modelling and simulation stage.

At the beginning of the DRF program, the SCs were capitalised with medicines or cash to procure medicines. Medicines are sold and cash from sales is used to replenish the stock. Customer orders received in hospitals as medicine prescriptions from patients were collected, and the sale price was determined. The costed prescriptions are then given to the patients to pay at the cashier and return with receipts to the pharmacy for medicine collection. Cash collected by the cashier of accounts department is deposited in the bank and used to pay suppliers for order procurement.

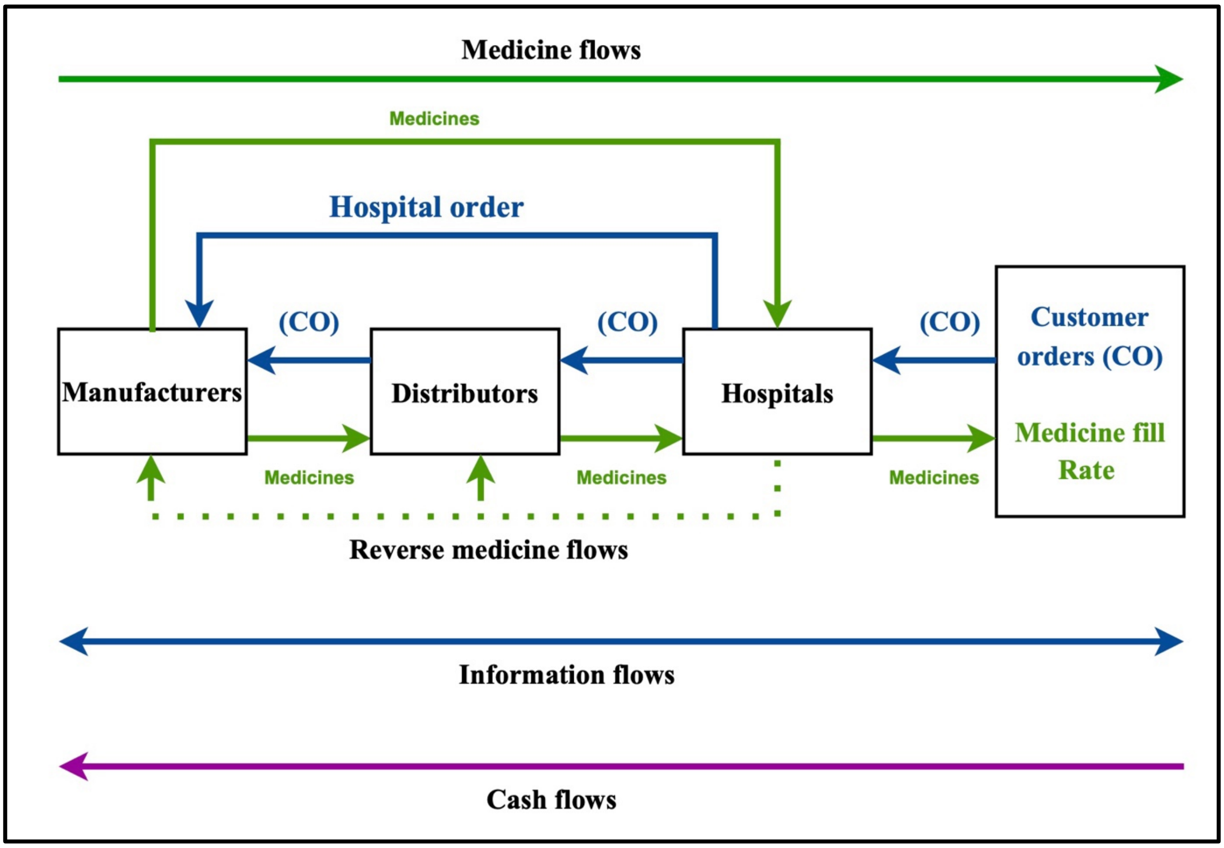


Figure 6.1: Integrated medicine supply chain with fill rate performance

6.2 Modelling problem statement

Case A started transforming its SC in 2017 by integrating all essential medicines handling and operations. Although the improvement in MFR was recorded as 6-75%, medicine stockout continues to be a problem for patients, as stockout ranges from 25-50% of the essential medicines. A medicine stockout is a source of concern for stakeholders and forms the basis of this study. Achieving a fill rate of 90-95 percent across all SDPs has been difficult for SC managers. This study attempted to develop a grounded theory of SCI to improve medicine availability and achieve a desired MFR of 90 percent and above. This study provides an understanding of the feedback, delays, and structure leading to improved fill rate, and offers clarity into the SCI phenomenon in public healthcare SCs. The model explores the behaviours that can help healthcare SCs avoid getting stuck in the arrested growth phase and move towards improved fill rates (Figure 6.2). The reference mode shows that, as the MFR increases, the stockout decreases.

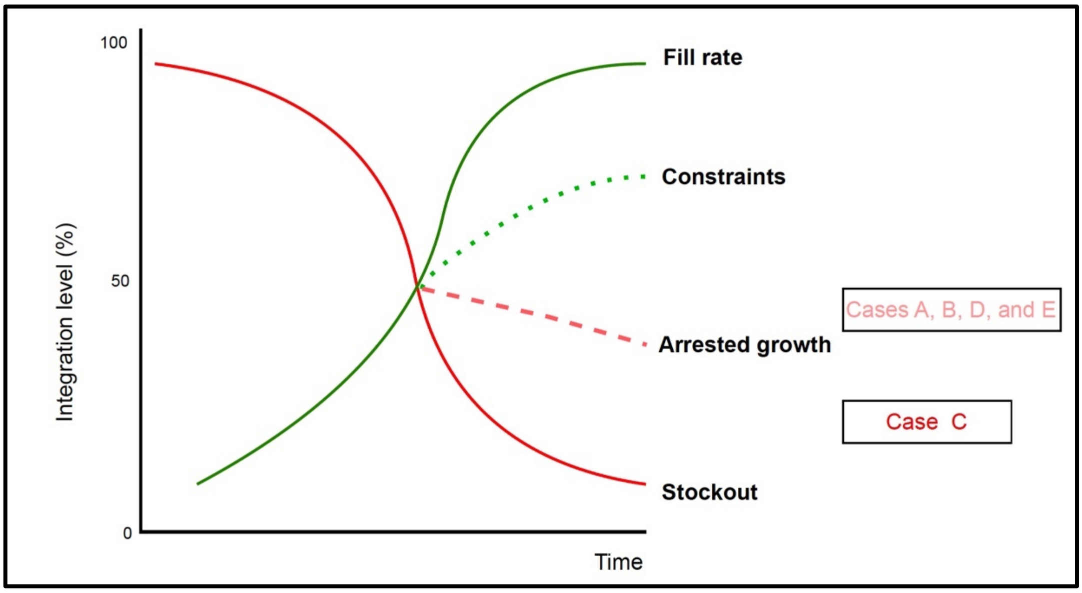


Figure 6.2: Reference mode for integrated supply chains

6.3 Developing the stock and flow diagram

The purpose of the model is to test whether increased integration leads to increased availability of medicines in the long run and decreased stockout. The model was developed using Vensim PLE Plus from January to December 2022 with over 40 model iterations. Several versions were discarded as model development progressed. Eight (8) stakeholders were continuously engaged across SCs to build and validate the model. Four stakeholders were supply chain experts, while the remaining four were SC practitioners. The Vensim software was chosen for this stage as it was easy to use and allowed the modeller to visualise the dynamic behaviour of the model.

6.3.1 Model time step and horizon

The time step for the model was one week as supported by the operations of the revolving fund weekly medicine requisition. Stakeholders validated the use of one week to view activities within a short time span of order fulfilment to hospitals. The choice of time step allows for short-term operational observations from weekly order fulfilment and long-term cumulative tactical and strategic outcomes. The time horizon was set at 100 weeks which is almost two years long enough to evaluate the progress of integration, as noted by stakeholders. Short-term evaluation of the transformation program was done quarterly, and observing the effects of the simulation over 7-8 quarters was agreed as adequate for decision-making. The program also needs to make decisions on the scale-up of integration to include more products. Therefore, 100 weeks was validated as sufficient for the modelling sessions. Scaling up the transformation program leads to an increase in customer orders. Model scale-up runs of ISC start at normal conditions until ten weeks when a five-week pulse of customer orders is introduced. This scenario shows the differences between the base run and sensitivity to increased customer orders. The long-term horizon of two years allows stakeholders to observe how the ISC handles the scale-up of essential medicine demand to improve the MFR.

6.3.2 Model boundary

The model boundary includes hospitals, medicine distributors, and manufacturers, as determined from interviews and stakeholders, to be critical in medicine SC operations. A three-tiered integrated SC model with boundaries around hospitals, distributors, and manufacturers of essential medicines was developed using Sterman's distribution model (Sterman, 2000). Variables from the interviews and the cross-case conceptual model were used to build a model of ISC. Hospitals replenish inventory from distributors and manufacturers and having the right mix of medicines improves the fill rate. Hence, availability depends on internal and external supplier policies. The hospital, distributor, and manufacturer inventories started in equilibrium, and customer orders were constant. This scenario shows that all customer orders are fulfilled at 100 percent. The period of hospital inventory holding is suitable for the system, as there was always some inventory owing to the hospital's stock policy. Accounts receivable ensured that hospitals were aware of the promise to pay from the credit sales of medicines to SDPs. Monitoring bad debt and the rate of payment helps the SC decide whether to reduce credit sales to SDPs and losses incurred from delayed or unpaid receivables. The sell price at a fixed markup of 20% allowed hospitals to recover the purchase price and the cost of running the program. Accounts payable are the commitment to pay suppliers for order fulfilment. Paying suppliers for order fulfilment helps hospitals meet their contract obligations. Weeks of payables ensured that suppliers get paid for medicines supplied, do not lose trust in the system, and continue to resupply medicines when needed. The cash at the bank guarantees payment to suppliers after medicine delivery. Adequate cash for continuous replenishments and operational expenses safeguarded the DRF program and ensured a cash flow.

Government funding and donor support were endogenous to the system, as mentioned by the interviewees. The DRF program is not responsible for the payment of staff salaries or the overhead cost of running the institution. This allowed stakeholders to understand the effect of external funding on the DRF program and its contribution to medicine availability. The ISC model internalises the financial management of revolving funds and procurement. The distributor replenishment cycle provided clarity on the operational delays and feedback that affect order fulfilment. The manufacturing cycle from production to work-in-process and finished medicine inventory management was captured by the ISC model. The model was continuously tested and debugged to understand the feedback that improved MFR (Figure 6.3).

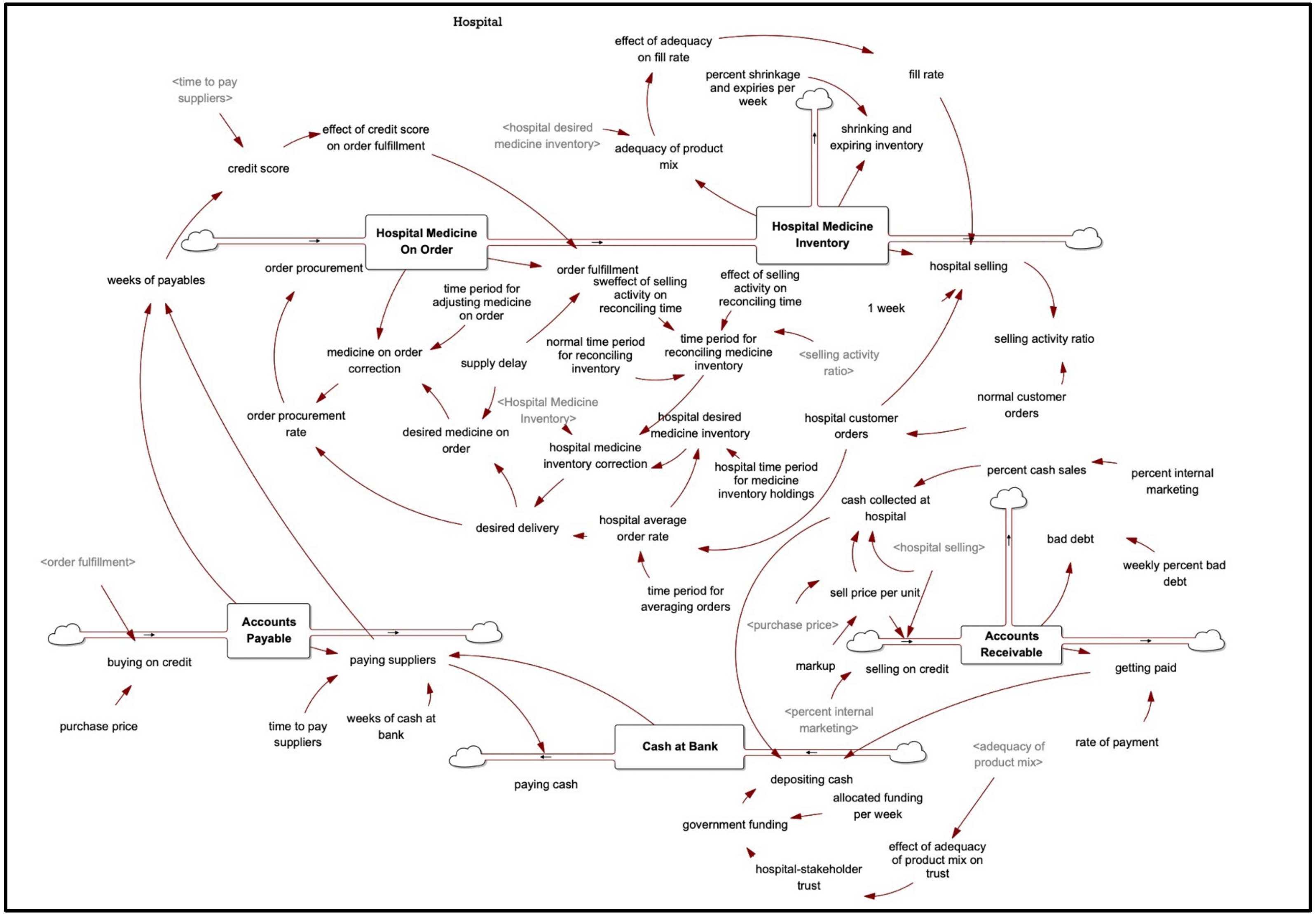


Figure 6.3: Model Structure Overview

The variables and feedback that affect the MFR were modelled as endogenous to the system, whereas the other variables were constant and exogenous to the SC. See Appendix VII for the full definitions of the variables used to build the integrated SC model. Some variables, such as medicine quality, drug abuse, benchmarking, and staff productivity, were outside the model boundaries (Appendix VIII). Hence, these variables are excluded from the ISC model. The reason for exclusion is that variables, such as medicine quality and drug abuse, are under the purview of specific government regulatory agencies. Hospitals are not responsible for the quality of medicines in the system or drug abuse. Productivity is a human resource function which requires a different category of stakeholders that are unrelated to the DRF and a longer time horizon than the ISC model.

6.4 Baseline scenarios of ISC model

The hospital SCs model had oscillations at the onset of modelling, even though demand was constant. A minimal 4% shrinkage leads to a decrease in the fill rate to 71% at the end of 100 weeks (Figure 6.4), assuming that all medicines were sold and cash was collected for medicines sold on credit every four weeks. The desired fill rate of 90 percent and above was selected as an improved performance, as stated by IS06: “If orders fill rate is around 90-95%, that is good” (IS06-06).

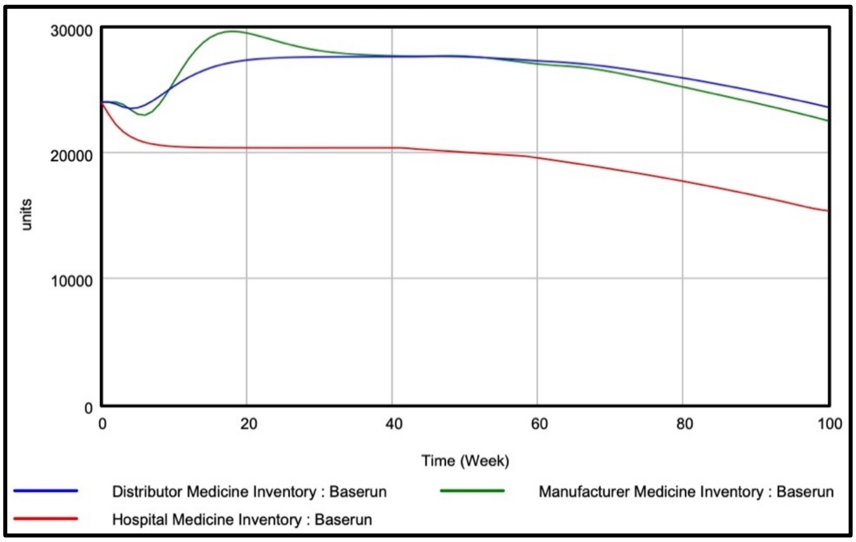


Figure 6.4: Hospital medicine inventory at 4% shrinkage and expiries

Shrinkage leads to a persistent decrease in medicines at the hospital and stockouts, but distributors and manufacturers respond to stockouts by stocking more inventory than needed.

Hospitals respond to medicine stockout by ordering more medicines than needed resulting in excess medicines which further reinforces shrinkage and expiries. Comparing hospital desired inventory and distributors shows a higher level of inventory in the presence of a constant customer demand (Figure 6.5)

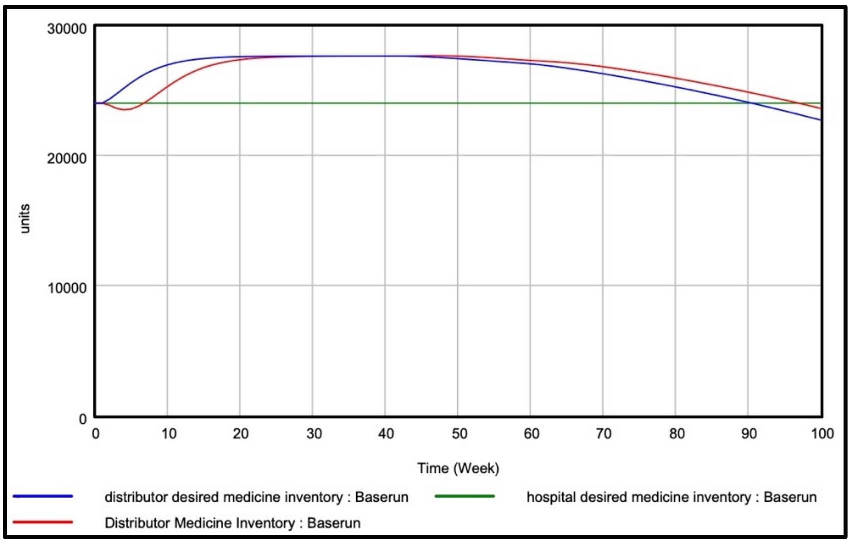


Figure 6.5: Distributor medicine inventory at 4% shrinkage and expiries

The distributor's desired medicine inventory is higher than what the hospital wishes to stock, which leads to expiries. Manual inventory management makes it cumbersome to determine shrinkage which decreases the hospital stock. Stockouts from hospitals also lead to stockouts from distributors, leading to the ordering of more medicines than is desired by hospitals. Excess inventory with distributors also triggers excess stock with manufacturers (Figure 6.6)

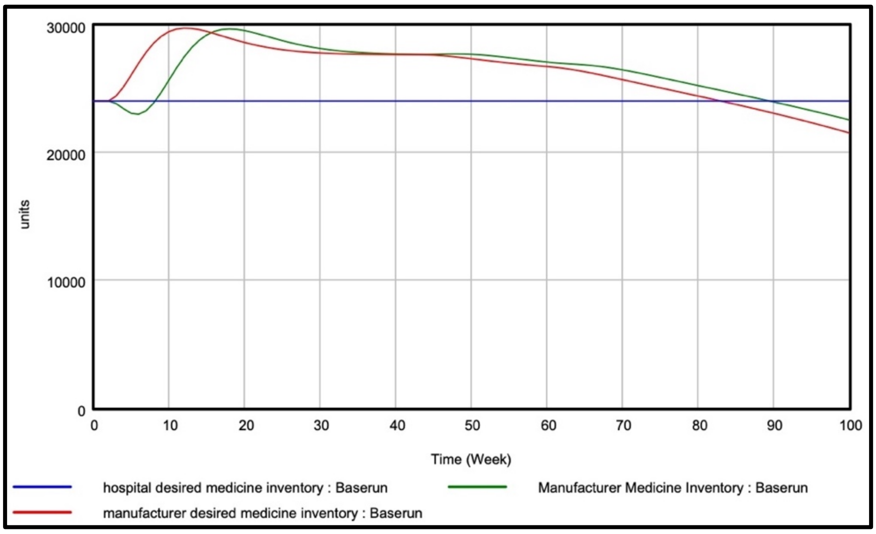


Figure 6.6: Manufacturer inventory at 4% shrinkage and expiries

Shrinkage in hospitals is perceived by medical suppliers as an increase in the consumption of medicines. The manufacturers' medicine stockout is overcompensated by the stocking of more medicines than required by hospitals. In addition, the hospital loses 92% of its cash at the bank, leading to defaults in payable accounts (Table 6.1). The cash at bank in scenario 1 is ₦5,310,760 which is equivalent to $11,458 at an exchange rate of $1=₦463.50 as of 30th March 2023. At the end of scenario 2, the cash at the bank is equivalent to $887.

Table 6.1: Effects of shrinkage on medicine inventory and medicine fill rate at 100 weeks

Observed effects	**Shrinking and expiring inventory (%)**	**Medicine inventory levels (units)**	**Cash at Bank (₦)**	**Fill rate (%)**	**Hospital-stakeholder (trust) (%)**
Scenario 1	0	24,000	5,310,760	100	100
Scenario 2	4	15,387	410,930	71	82

The hospital fill rate without shrinking and expiring inventory is 1 (100%) (Figure 6.7). The fill rate unit was Dimensionless (Dmnl). Shrinkage leads to a loss of stakeholder trust in the system (see Figure 6.8). Decrease in fill rate to 71% leads to a decrease in hospital-stakeholder trust from 100% to 82%, and cash flow (Figure 6.9)

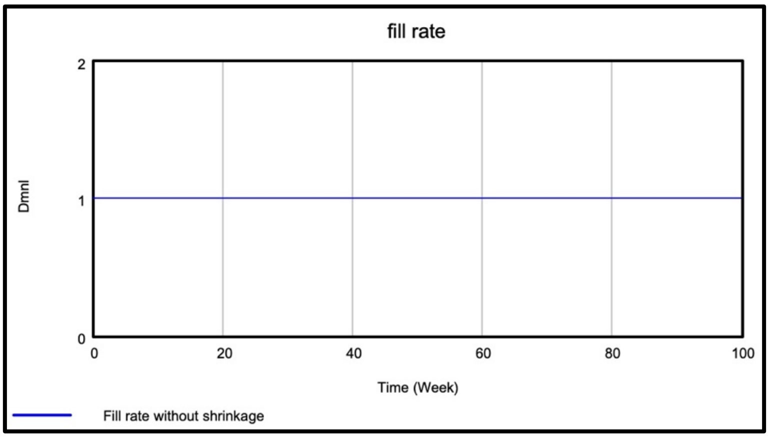


Figure 6.7: Hospital medicine fill rate without shrinkage

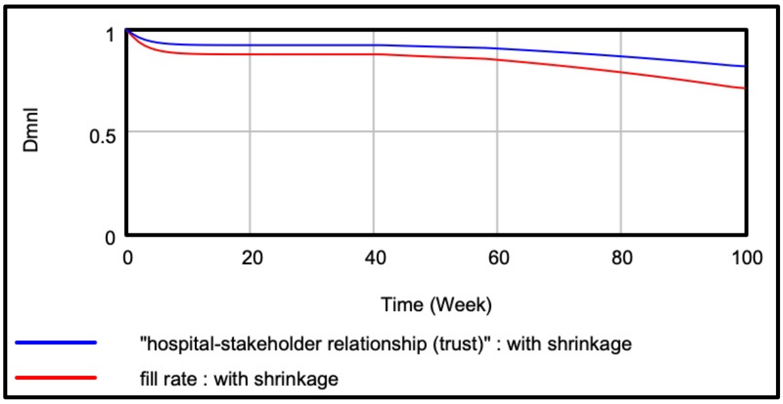


Figure 6.8: Hospital-stakeholder trust with shrinkage

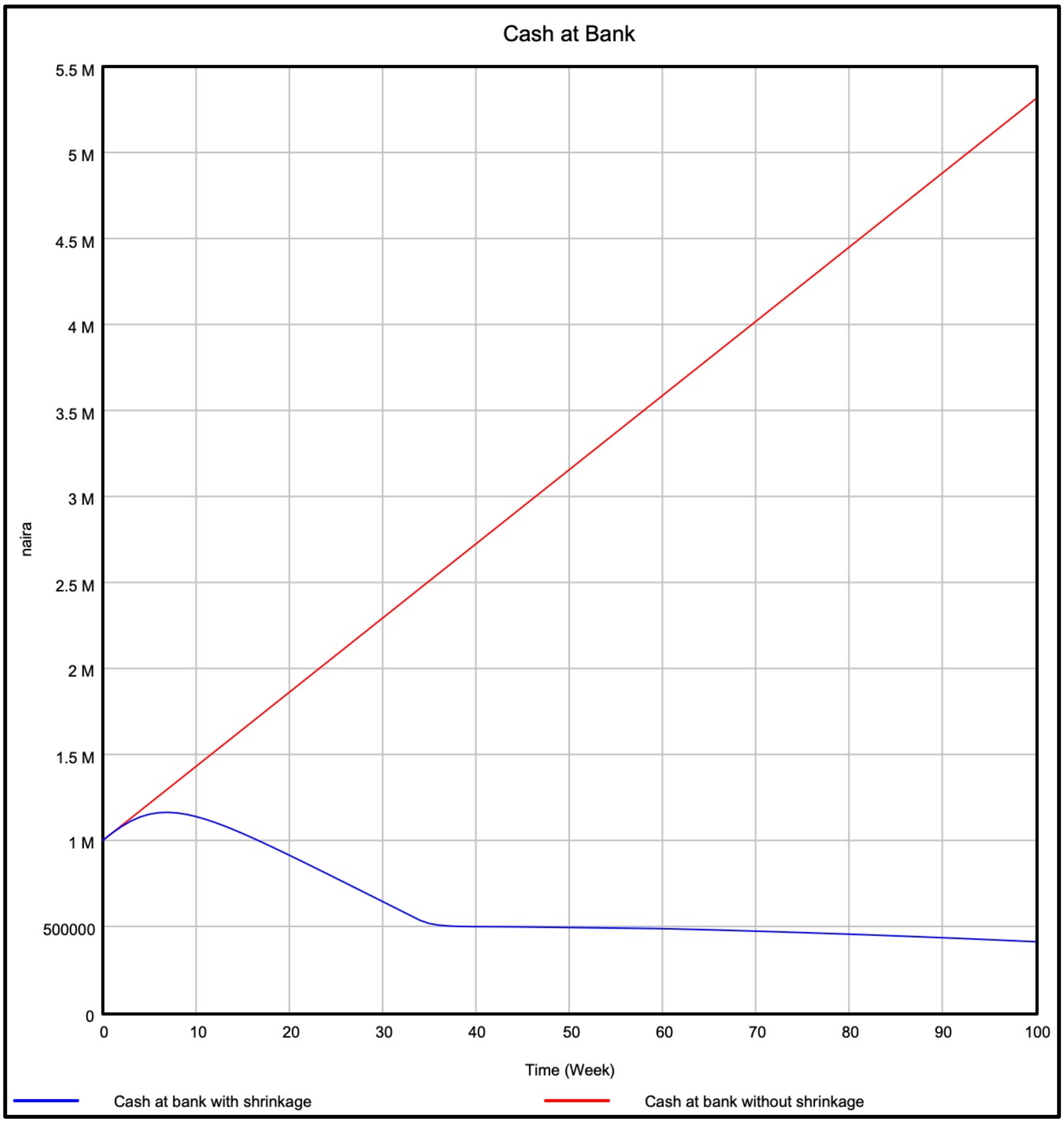


Figure 6.9: Hospital cash at bank with shrinkage and decreasing stakeholder trust

At the end of 100 weeks, cash at the bank is ₦410,930, which can only replenish 21% of the desired hospital inventory to attain a fill rate of 71% (Figure 6.5). Accounts payable rose to ₦2,113,470 making it difficult for hospitals to replenish inventory with a credit score of 0.4. Suppliers cannot fulfil orders from hospitals with less than average credit scores, leading to sustained medicine stockouts. The hospitals send out orders to replenish stock, but due to a lack of visibility, the distributor and manufacturers order more medicines than required by hospitals (Figure 6.10). The hospital was still stocked out at the end of the 100 weeks.

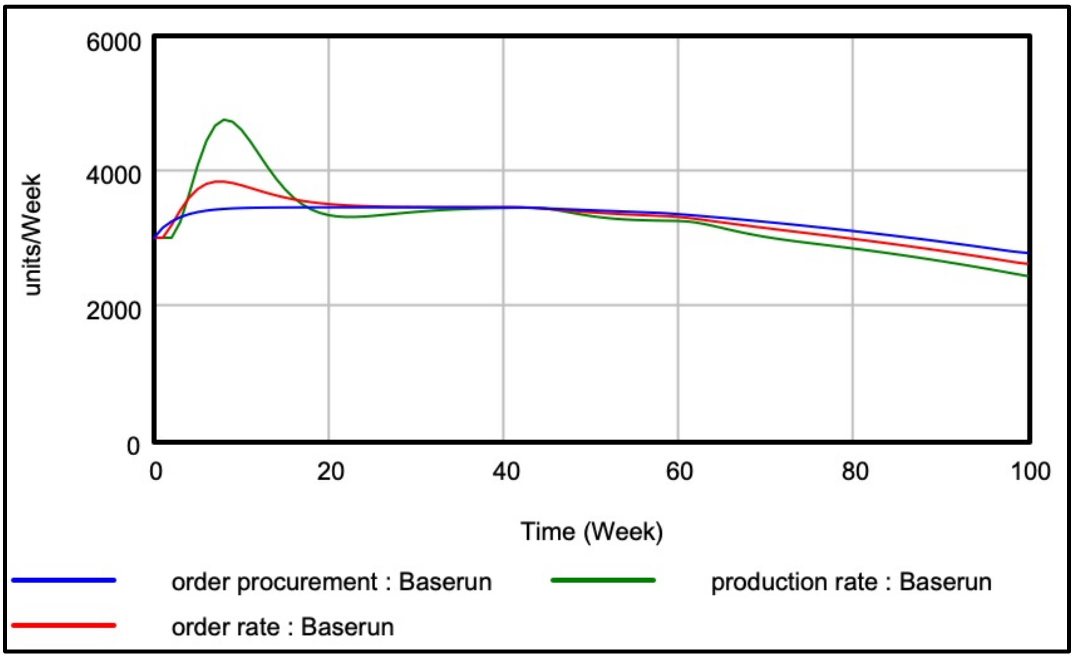


Figure 6.10: Replenishment of medicine inventory across integrated supply chain

When the MFR was 100%, every customer received all of the desired medicines prescribed in the hospital. Supplier delivery delays led to medicine stockouts and decreased fill rates (Figure 6.11).

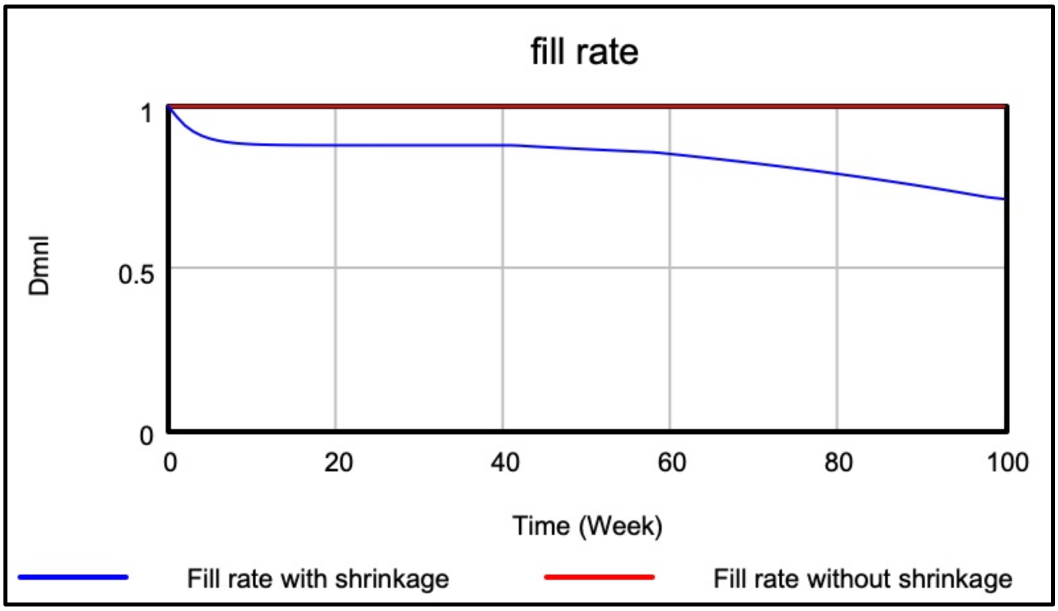


Figure 6.11: Hospital medicine fill rate with shrinkage across integrated supply chain

Medicine shrinkage leads to stockouts and panic buying in hospitals. The staff sends orders for replenishment of the stock more than is required, and this scenario initially leads to an increase in hospital order fulfilment, followed by increased distributor shipment and more production from manufacturers to close the inventory gap. The pressure to close the gap leads to oscillations in the model which are balanced by a decrease in the inventory below the desired medicine inventory level and a reinforcing stockout loop (Figure 6.12). Shrinkage also leads to a decrease in cash flow (Figure 6.13)

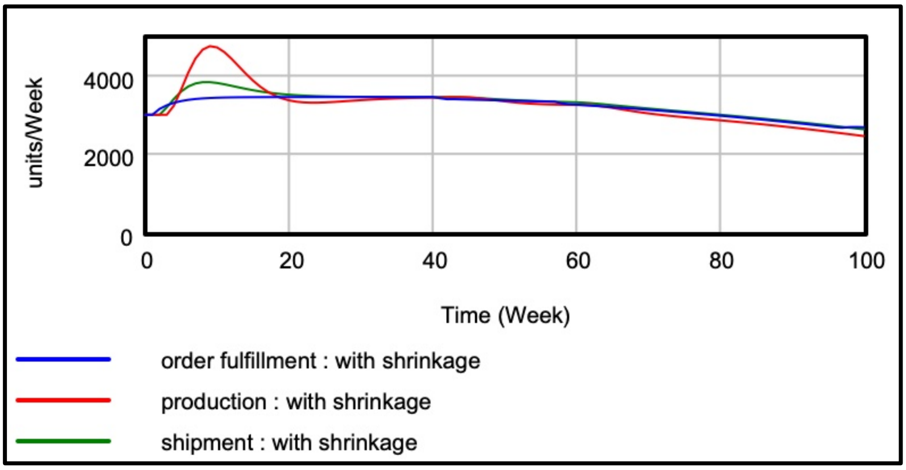


Figure 6.12: Increasing medicine inventory across integrated supply chain

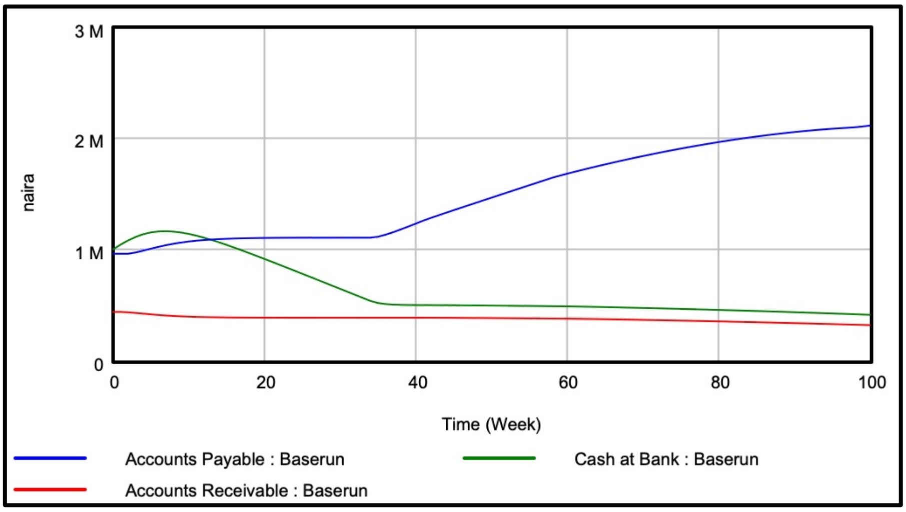


Figure 6.13: Hospital Cash flow with shrinkage

6.5 Effect of shrinking inventory on cash at bank

When shrinkage is at 5%, the revolving fund grows to over ₦1 million and then drops to ₦500,000 as against the steady growth to ₦5.25 million when there is no shrinkage or expiry of medicines (Figure 6.14 & figure 6.15). The current hospital shrinkage from damages, pilferages, and expiries of 5% leads to the gradual collapse of the DRF program. This scenario depicts the significant effect of shrinkage on the cash at the bank which prevents the process of medicine replenishment as funds become depleted. Even a minimal shrinkage level of 2% has a profound effect on the cash at the bank. The DRF program became stunted and stopped growing. The depletion of cash at banks leads to increased accounts payable from ₦1 million to over ₦2.5 million. Inability to pay suppliers at the agreed contract time with increasing weeks of payables reduces trust and the credit score of the hospital SC, locking the system in a vicious cycle.

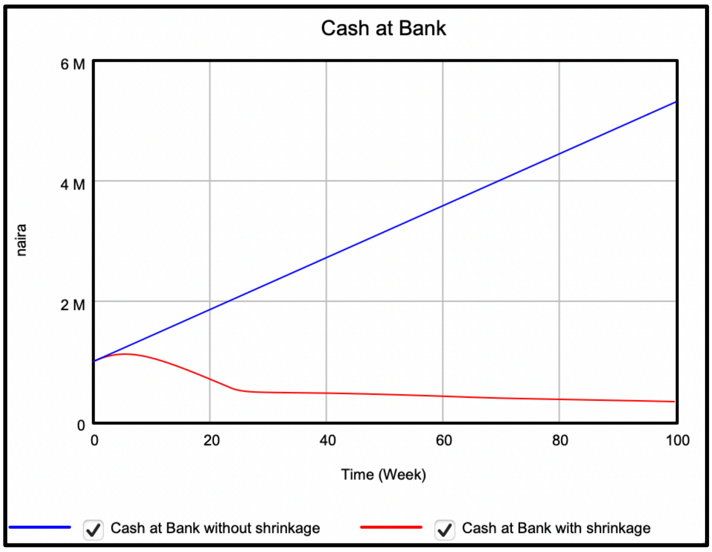


Figure 6.14: Cash at Bank with shrinkage and expiry of medicines

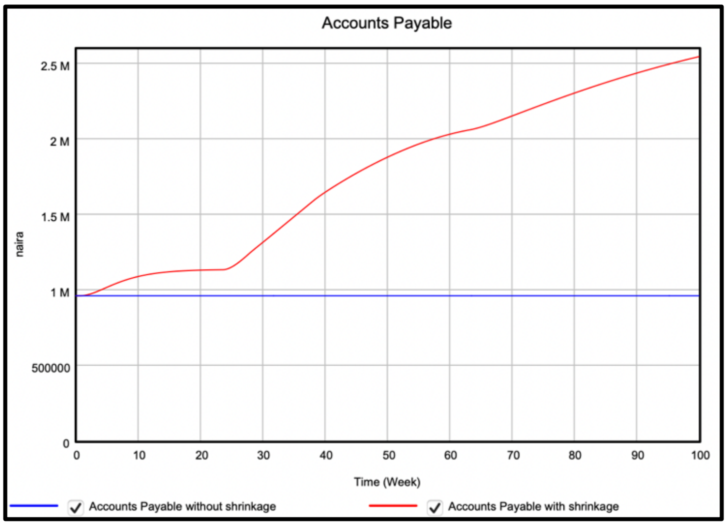


Figure 6.15: Effect of shrinkage and expiries on Accounts Payable

The reinforced procurement loop is balanced by cash collection feedback, which constrains the capacity to buy more medicines. The effect of shrinking inventory due to damages, pilferages and expiries leads to leakages of cash. Cash depletion prevents SCs from fulfilling their payment obligations with the suppliers. Hence, depleting trust and uncertainty in paying suppliers leads to increased payables and the collapse of DRF, as shown in Figure 6.16.

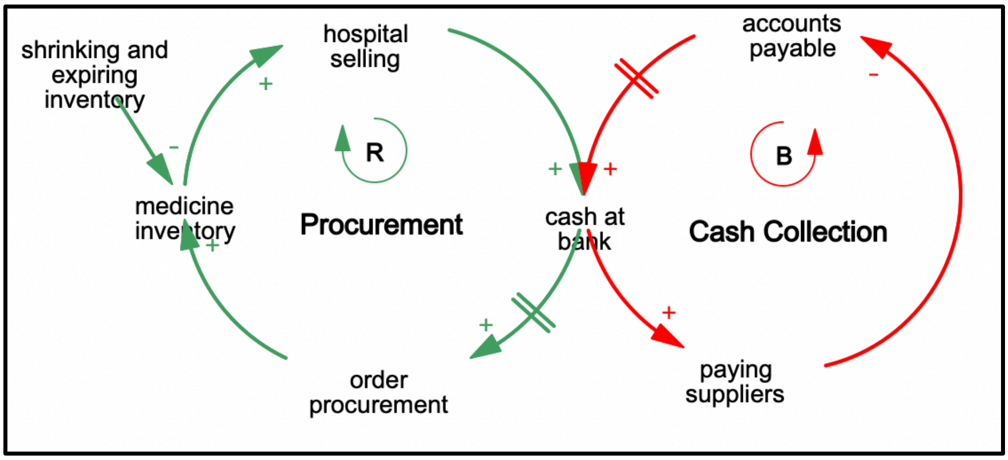


Figure 6.16: Effect of shrinking and expiring inventory on procurement and cash collection

6.6 Effect of shrinkage and expiries on hospital medicine inventory

The effect of 5% shrinkage, pilferage, and expiries on medicine inventory led to a drop in the desired inventory from 24,000 to 11,500 units which is below 50% of the desired level (Figure 6.17). At a fill rate of 57% which is 33% of the desired service level of 90%, critical medicines are out of stock, as shown in figure 6.18. Increasing the weekly allocation of funds to ₦32,800 improved the MFR by 85% in the presence of a 5% shrinkage. A desired fill rate of 90% can only be achieved when the shrinkage is equal to or less than 3%. The medicine inventory level is 21,000 units at a 90% fill rate (Figure 6.18).

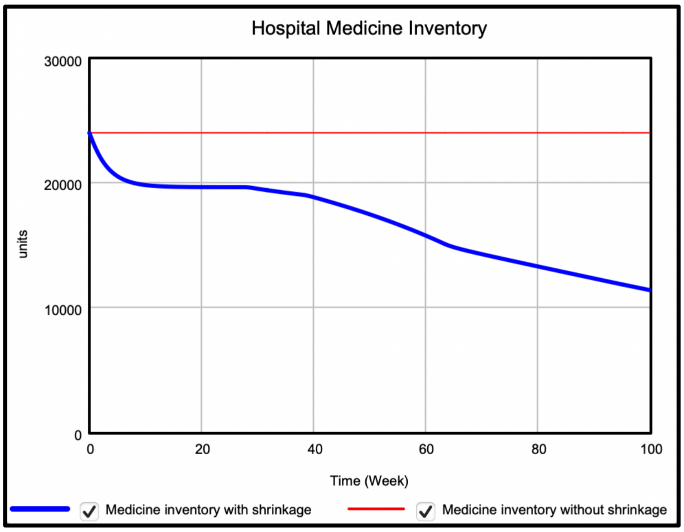


Figure 6.17: Effect of shrinkage and expiries on hospital medicine inventory

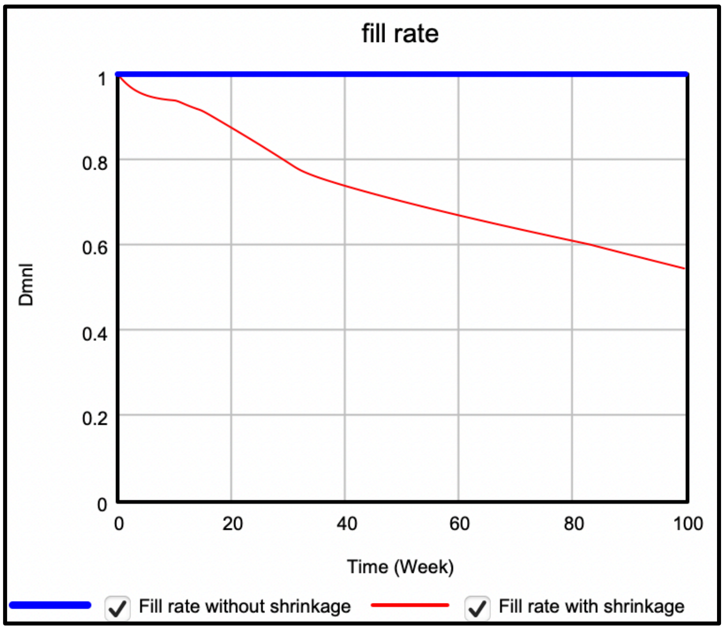


Figure 6.18: Effect of shrinkage and expiries on medicine fill rate

6.7 Effects of shrinking and expiring inventory on availability of medicines

The DRF staff does not immediately perceive stagnation in cash growth, as it is masked by selling on credit and growing account receivables. Accounts receivable as a promise of cash to be received by the hospital is considered an asset, hence giving an assurance that money will be received in the future for order fulfilment. Shrinkage, damage, and expiries reduce inventory, leading to reduced receivables. Payment of receivables increases cash at the bank but shrinkage depletes receivables without a commensurate increase in cash (Table 6.2). Reducing cash impedes procurement, leading to decreasing inventory below the desired level. Inadequate inventory reduces the fill rate performance of the SCs. On the other hand, shrinkage also increases accounts payable which promises to pay suppliers for medicines received by hospitals (Table 6.3). As the number of weeks of payables increases, payment of medicine suppliers' stalls and uncertainty leads to decreasing trust in the hospitals from the suppliers. Trust issues appear to affect order fulfilment in hospitals, leading to stockouts, as reported by supplier ES45:

"…once the orders are collected, the commercial department … the first thing they will do is to is to check the credit status of the … customer. So, they look at the customer receivable to understand whether the account is aged or not aged. So whether the account has exceeded its credit limit if the account … is within the normal credit limits days …not gone beyond ninety days. So, the account will be okayed to be approved for the next stage. So, the customer cannot buy more than that, the customer has to make payment to create a space to raise more". (ES45-01)

A 5% shrinkage leads to 13 weeks of payables and a low credit score of 0.31, leading to a decrease in the fill rate to 63%. Suppliers do not replenish orders received from hospitals with low credit scores, which leads to medicine stockouts.

Table 6.2: Effects of shrinking and expiring inventory on fill rate after 100 weeks

Observed effects	Shrinking and expiring inventory (%)	Medicine inventory levels (units)	Cash at Bank (₦)	Fill rate (%)
Scenario 1	2	22,041	2,060,120	93
Scenario 2	3	21,177	614,779	91
Scenario 3	5	12,833	361,990	63
Scenario 4	6	9,325	287,439	49

Table 6.3: Effects of shrinking and expiring inventory on weeks of payables

Observed effects	Shrinking and expiring inventory (%)	Accounts receivable (₦)	Accounts payable (₦)	Weeks of payables
Scenario 1	2	408,700	1,038,370	4
Scenario 2	3	396,102	1,072,940	4
Scenario 3	5	279,888	2,366,190	13
Scenario 4	6	222,750	2,624,770	18

6.8 Effect of medicine shrinkage expiry and damages on accounts payable

Shrinking and expiring inventory has led to an increase in accounts payable. Order fulfilment to the hospital decreases, leading to a stock level of 32% of the desired medicines. A 6% shrinkage led to a medicine stockout in the hospital and reduced the fill rate by 42% (Table 6.4).

Table 6.4: Effect of medicine shrinkage expiry and damages on accounts payable

Observed effects	Shrinking and expiring inventory (%)	Weeks of payables (weeks)	Accounts payable (₦)	Fill rate (%)
Scenario 1	2	4	1,038,370	93
Scenario 2	3	5	1,375,860	90
Scenario 3	5	15	1,758,000	57
Scenario 4	6	22	2,708,180	42

6.9 Effect of account receivables payment on cash at bank

Hospitals and departments within the hospitals receive medicines from the pharmacy in Cases A, B, C, D, and E. Delays in payment of receivables from departments and hospitals lead to a decrease in cash at the bank which increases the number of weeks payable from 4 weeks to 12 weeks and reduces the credit score of the hospital to 0.33. The credit score enables the medicine supplier to make decisions on order fulfilment to hospitals. A credit score of 0.33 leads to a fill rate of 77%, which is below the desired fill rate of 90% (Table 6.5). An increase in account receivables leads to a decrease in cash at the bank which reduces the rate of paying suppliers and increases payables. An increase in payables reduces the credit score and capacity to procure more medicines, leading to stockout. Even when the system attempts to increase cash collection, shrinkage depletes stock, trapping the system in a vicious cycle of medicine stockout, as shown in figure 6.19.

Table 6.5: Effects of accounts receivable rate of payment on cash at bank and credit score

Observed effects	Payment rate for accounts receivable (weeks)	Cash at Bank (₦)	Credit score	Fill rate (%)
Scenario 1	4	5,310,760	1	100
Scenario 2	6	4,851,290	1	100
Scenario 3	30	1,156,440	0.9-1	100
Scenario 4	104	311,696	0.3	69.5

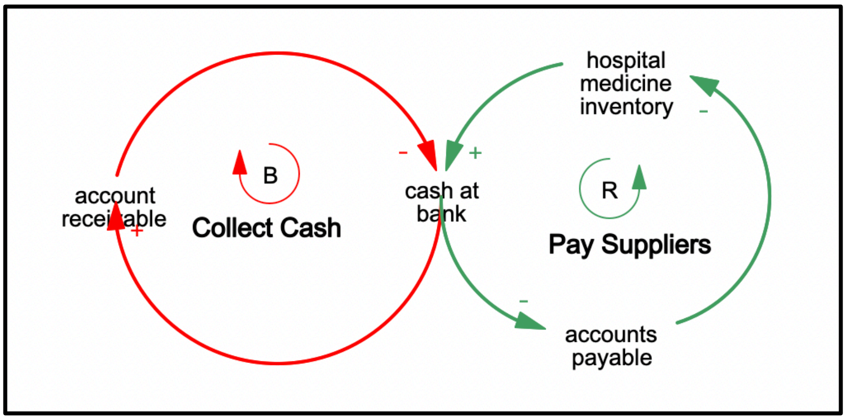


Figure 6.19: Effect of accounts receivable payment on supplying hospital medicine inventory

Delays in the payment of receivables lead to a decrease in cash at the bank and credit scores from the suppliers of medicines. The decrease in cash at banks from accounts receivable is progressive, as it is considered promising to receive payment from buyers. A default in payment for 104 weeks leads to weekly bad debt which depletes the DRF account. A decreasing credit score determines the decisions of medicine suppliers not to fulfil orders, as the hospital is deemed to be at risk of defaulting on payment for medicines. When hospitals do not receive medicines from suppliers, medicine stockouts increase and the fill rate performance drops.

6.10 Effect of account receivables payment on accounts payable

Selling DRF medicines on credit accumulates accounts receivable. The payment rate for account receivables is usually delayed by departments and hospitals that collect medicines from pharmacy departments. In some cases, the delay can extend to more than 52 weeks (see Table 6.6), leading to bad debt. Bad debt is a source of leaking funds in the DRF, which makes it difficult for the organisation to meet its obligations to suppliers, leading to an increase in account payables and weeks of payables.

Table 6.6: Effects of accounts receivable rate of payment on fill rate

Observed effects	Payment rate for accounts receivable (weeks)	Weeks of payables (weeks)	Accounts payable (₦)	Fill rate (%)
Scenario 1	4	4	960,000	100
Scenario 2	30	4	960,000	100
Scenario 3	52	8	1,758,000	94
Scenario 4	104	15	2,364,660	70

6.11 Effect of transformation program scale-up on fill rate

The scale-up of the ISC program led to increased customer orders in week 10 in the simulation. The fill rate at scale-up was simulated by increasing customer orders by 50% at week 10 for five weeks. The fill rates with 9% and 1% shrinkages were 17% and 96%, respectively (Figure 6.20). Reducing shrinkage increases the fill rate. This shows that shrinkage must be reduced before scale-up can be successful, with a 96% fill rate. When shrinkage is not minimised, stockouts persist until the DRF programme fails.

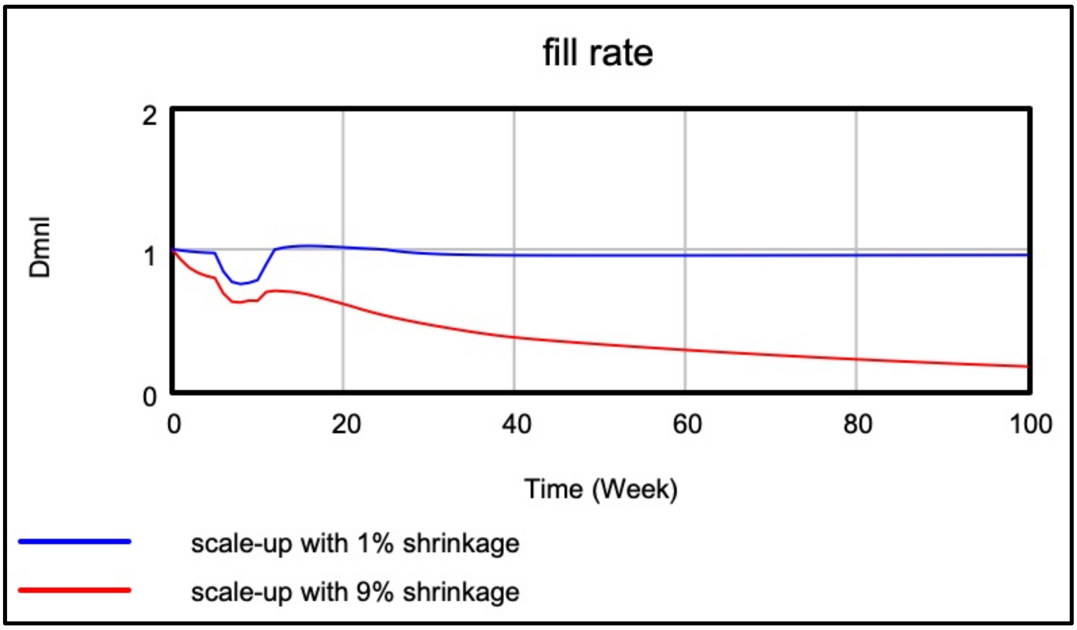


Figure 6.20: fill rate with shrinkage at scale-up

6.12 Model validation and stakeholder consultations

The model was validated using 11 model tests (Sterman, 2000). Two supply chain experts from Case A and two from Case B were engaged in the stakeholder consultation and validation of the model. The structure of the model was tested iteratively to ensure that none of the stocks had negative values. Doubling customer orders using step and pulse functions in the Vensim software showed no negative stock value. The dimensional consistency of the model showed that all the units and formulas were correct (see Appendix VII). The model parameters were observed and discussed during the stakeholder consultations. All model parameters have meaning and reasonable values, as noted by the participants, and were identified from interviews and stakeholder consultations (Appendix VII-XIII). Step and pulse tests were performed, and the model was debugged and retested as a reality check. The model time step was cut in half, and alternate integration methods were tested. There was no change in model behaviour. The behaviour reproduction test was conducted using a time series for three high-consumption essential medicines across five study organisations. The total unit counts of the three reference medicines, Metronidazole, Artemether plus Lumefantrine, and Paracetamol, were determined. The on-shelf availability of medicines was determined by multiplying the units of available medicines with the sale price averaged and normalised to harmonise the scale. The normalised average medicines were plotted on a graph (Figure 6.21), and a trend line was drawn to compare the behaviour of medicine inventory availability over time with the simulation base-run scenario (Figure 6.22). Comparing trends from the normalised average medicine inventory in Case A with the trend in the base scenario of the model at 9 percent shrinkage and delayed accounts receivable payment rate of 54 weeks shows the same downward trend at a steady state. The model behaviour shows an accelerated decrease in medicine inventory which is similar to the actual behaviour in Case A. The model passed the behaviour replication test.

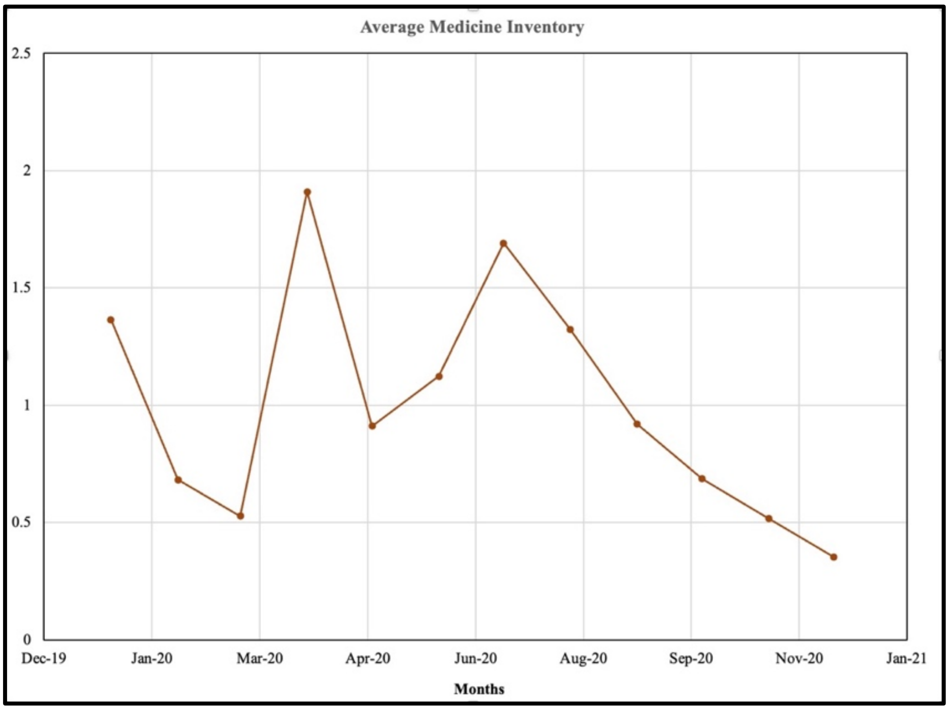


Figure 6.21: Normalised average medicine inventory for essential medicines

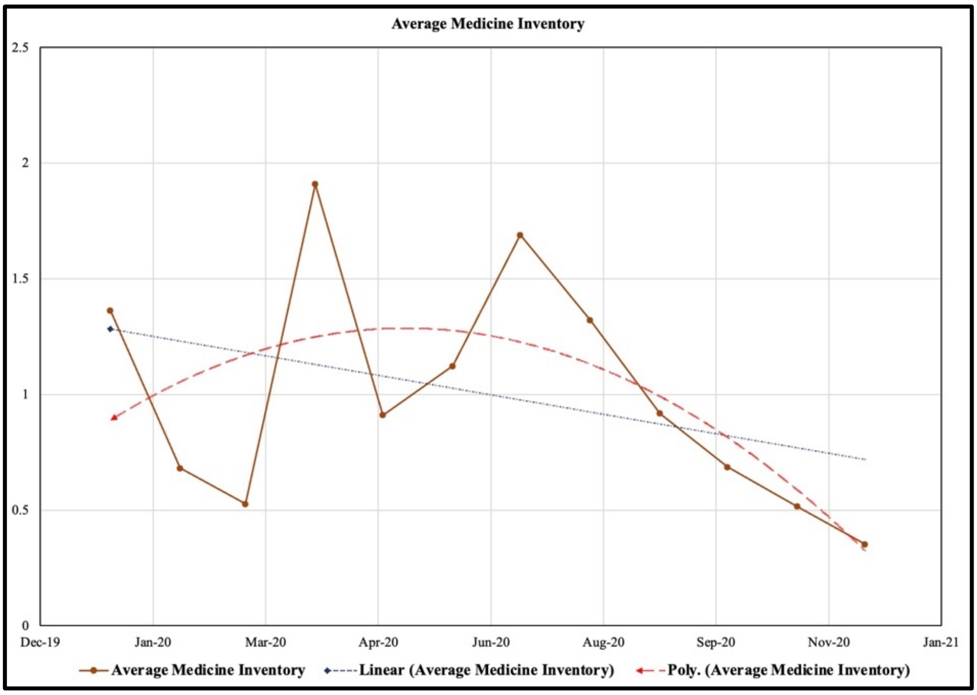


Figure 6.22: Trendlines for average medicine inventory

The reference mode of key variables shows that an increase in shrinking and expiring inventory leads to a decrease in the fill rate and cash at the bank. The ordering process was not perfect, and there was oscillation in the model from January to June. After six months, there was a downward long-term medicine stockout. The sum of the number of oscillations led to a downward trend. The polynomial trend showed an accelerating downward trend, indicating that the SC did not experience an ordering problem which is represented by oscillations. The linear trend shows a sharp downward decrease in medicines from six months (Figure 6.23). Medicines are tracked using cash values in the DRF supply chains.

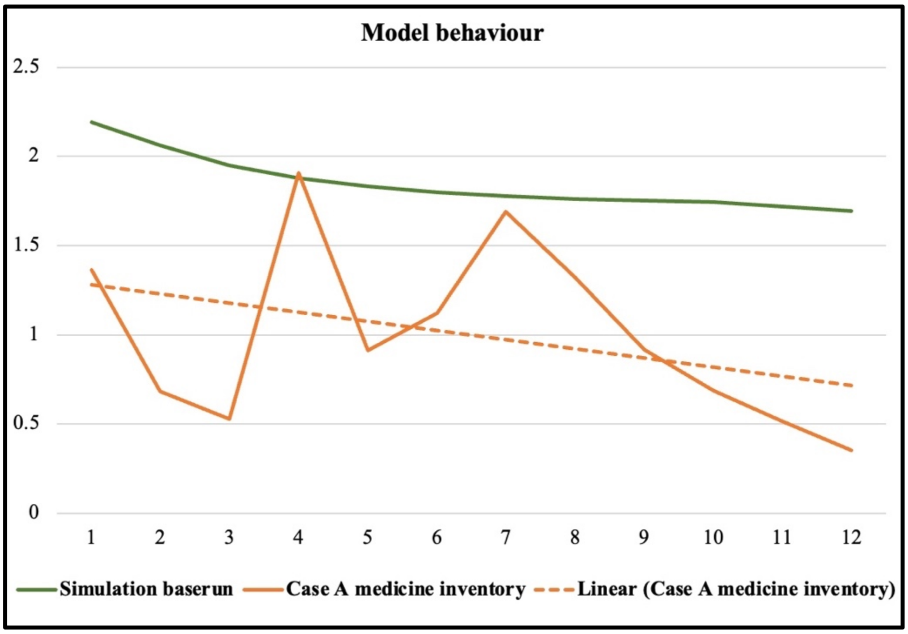


Figure 6.23: Model behaviour in comparison to actual medicine inventory trend

The simulation behaviour model was validated by stakeholders to fit the actual medicine inventory behaviour. The family member test showed that the model can generate the same behaviour for other classes of medicines and health products using a revolving fund model. The model behaves like a replenishment model with oscillating goal-seeking behaviour. The model showed surprise behaviour in that shrinkage led to the decapitalisation of the revolving fund faster than bad debt. Sensitivity analysis was conducted by reducing the payment period of accounts receivable to four weeks to increase the quantity of medicine inventory. Reducing the shrinkage also improved the fill rate. A key performance indicator dashboard was developed and used by supply chain experts to increase MFR by 90%. The dashboard was used by the participants to control the medicine inventory, account receivables, account payables, and cash at the bank (Table 6.7). Behaviours that will improve the system and fill rate were discussed and simulated.

Table 6.7: Model validation for integrated supply chain model

Model validation test	Test description	Observed model effects
Structure assessment	Model structure was tested using extreme values to ensure stocks are not negative	None of the stock was negative
Dimensional consistency	Units check function was used to check model consistency	All units and formulars were correct
Parameter assessment	Model variables were checked for accuracy and consistency during stakeholder consultations	All parameters have meaning, and reasonable values.
Extreme condition	Step and pulse test using extreme values	Behaviour was consistent with change
Integration error test	Cut time step in half and alternate integration methods	No change in model behaviour
Behaviour reproduction test	Use actual data as reference mode to check simulation behaviour	Simulation model showed the same behaviour with the reference
Family member test	Use a different class of DRF medicines to simulate model	model behaves like other replenishment model with oscillating, goal seeking behaviour
Surprise behaviour test	Check model scenarios for unexpected behaviours	Shrinkage led to decapitalisation of the revolving fund faster than bad debt
Sensitivity analysis	reduce payment period of account receivable and shrinkage also improves fill rate.	Reducing payment rate to 4 weeks and shrinkage to zero increases quantity of medicine inventory and fill rate
System improvement test	Evaluate model improvement	Key performance indicator dashboard was designed and used for improving fill rate to 90%

The integrated model was shared with two supply chain experts in Case A for a comparison with the baseline performance management system. Validation sessions with stakeholders showed that Case A aimed to reduce shrinkage and expiries to 1% or less to improve the fill rate. Participants reported that the model could be used by any supply chain to increase the fill rate and could be adapted to solve other problems. Although Case A adopted a physical dashboard (Figure 6.24) for managing medicine availability, the use of real-time simulation runs from this research provides real-time visibility of policies on decision-making and helps select, test, and interact with different policies. The real-time dashboard in Figure 6.25 motivates the operations staff to explore performance indicators and define policies for increasing the medicine fill rate. It provides a holistic view of the system behaviour driving medicine inventory availability and enables the tracking of decisions and outcomes on reducing stockout. The integrated dashboard allows system operators to visualise the improvements arising from reducing shrinkage and other policies. The staff uses the current physical dashboard to track the lead time and rate of return. The effects of these policies cannot be tracked or interacted with, unlike the use of an integrated real-time dashboard which shows the effect of medicine shrinkage on fill rate and financial performance. The use of an integrated dashboard goes beyond measurement to enhance performance management and improve the fill rate. Unlike the physical dashboard, which measures internally focused metrics, lead time, rate of return, stock-out rate, damages, picking accuracy, and supplier performance. The integrated dashboard measures end-to-end operations using internal and external performance indicators, such as fill rate, product mix, and cash flow.

Figure 6.24: Physical dashboard for managing key performance indicators

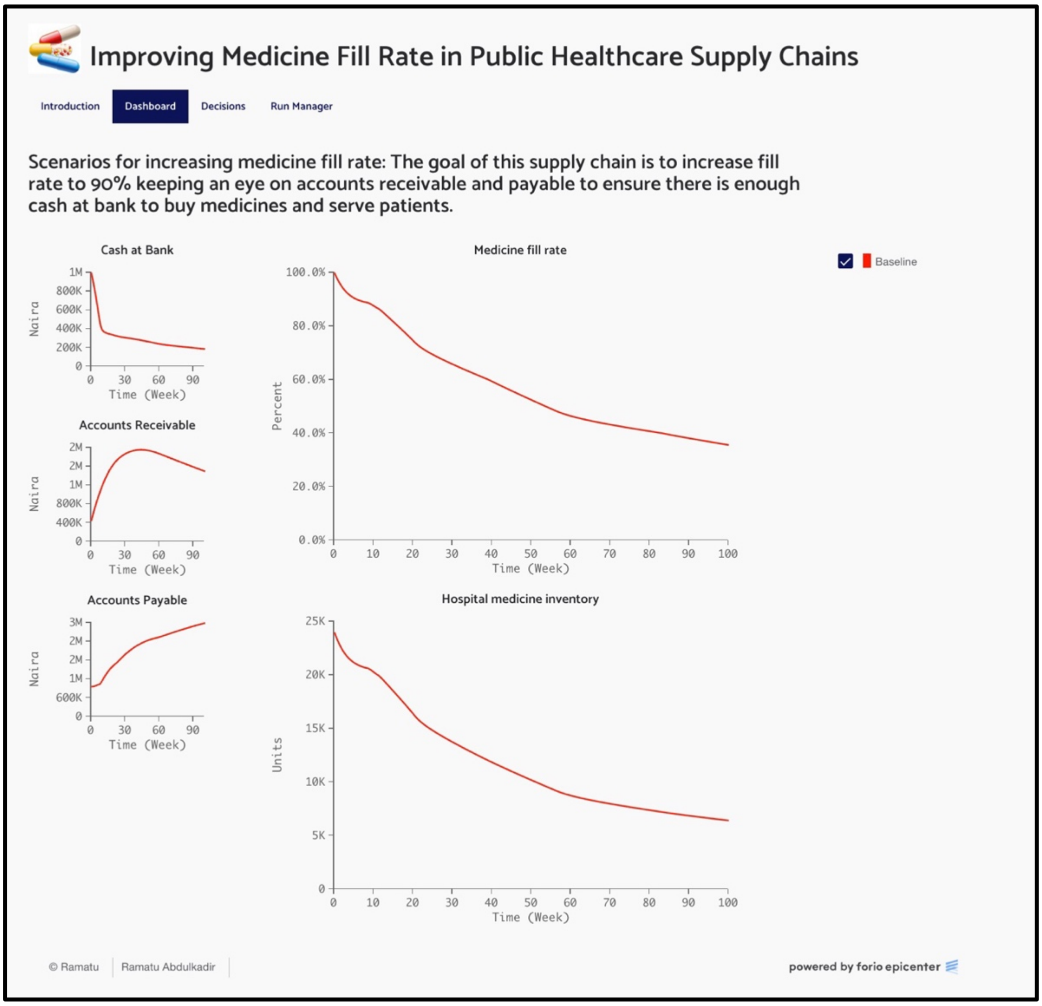


Figure 6.25: Real-time dashboard view of baseline medicine availability model

The benefits of measuring and managing performance in real-time are outlined in Table 6.8 below. A real-time dashboard allows managers to test and simulate different policies and combinations to increase the fill rate.

Table 6.8: Benefits of adopting real time dashboards for improving medicine availability fill rate

Physical dashboard features	**Real-time dashboard benefits**
Cumbersome to fill and maintain	Easy to explore
Fixed and cannot be moved around	Can be moved around
Not always available for use	Always available for use
Cheap to use but expensive in the long run as it is difficult to implement policies	Expensive to use, requires internet connectivity but cheaper in the long run as is easy to implement policies
Non-interactive and demotivates users	Very interactive and motivates users to keep exploring
Support decision-making with great effort	Supports decision-making on the fly.
Not effective for complex supply chains	Effective for complex medicines decision-making
Difficult to connect actions to performance output	Easy to connect actions to performance
Cannot be synchronized with partners systems	Cloud-based and easy to synchronize with partners systems
Cannot be used by multiple users at once	Accessible to multiple users in different locations

6.13 POLICY ANALYSIS

Six policies were tested to increase the MFR. Stakeholders interacted with the real-time dashboard by moving sliders to test different policies by increasing and decreasing values and observing their effects. This was followed by a discussion of the effects on the MFR. Participants explored scenarios for fill rate and other variables. The reasons behind these behaviours were discussed, along with policy combinations that improved medicine availability and customer order fill rates. Strategies for implementing the policies were also analysed. Each scenario was compared to the baseline and discussed by the stakeholders.

6.13.1 Medicines shrinkage and expiries policy

Case A is targeting 1% shrinkage and expiries which will improve fill rate to 97% above desired level (Figure 6.26). The simulation of the model baseline shrinkage at 9% shrinkage with a 17% fill rate at 100 weeks was compared with the desired shrinkage of 1% (Figure 6.27). Policies to reduce shrinkage include digitalising the SC processes of inventory management and product handling to minimise wastage and pilferage. Introducing sales and operations planning to match demand and supply will reduce expiries and rate of return of products from hospitals. The use of digital platforms to integrate point of sales information across integrated networks enables planning throughout the SC. Medicine manufacturers can plan with raw material suppliers to minimise uncertainties. Providing digital platforms to hospitals provides visibility to medicine flows and reduces the need to request excess medicine. The shrinkage goal of 1% did not align with the organisational fill rate performance target of 90%. At 1% shrinkage, the fill rate was above 90%, and at 2% shrinkage, it decreased to 76% (Figure 6.26). The scenario showed that a fill rate of 90% could be achieved only with a combination of policies.

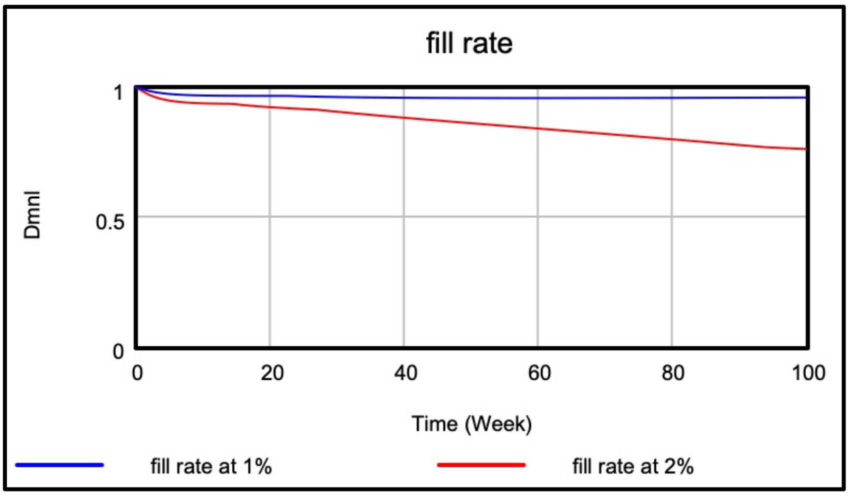


Figure 6.26: Fill rates at 1% and 2% shrinkages

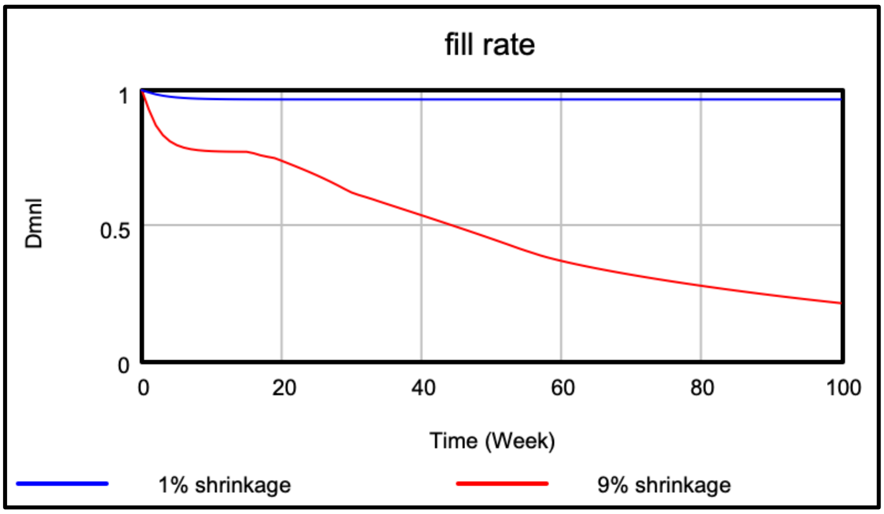


Figure 6.27: Fill rates at 1% and 9% shrinkages

6.13.2 Government medicines allocation policy

Policies on cash collection and receivable payments fall under government jurisdiction to enable automated digital cash processes. Some stakeholders believed that the government needed to increase medicine funding to hospitals to improve the MFR, as observed during the interviews. Increasing fund allocation from the baseline of ₦1000 to ₦85,714/week increases the MFR from 17% to 56% (Figure 6.28). Even with a monthly allocation of ₦342,856, a fill rate of 90% could not be achieved. Doubling the weekly funding to ₦171,428 per week did not increase the fill rate by more than 77% (Figure 6.29). Scenario testing of ₦1,000,000 weekly allocations did not increase fill rate beyond 77%. This shows that increasing government funding will not increase the fill rate by more than 77%, with a 9% shrinkage. At the end of 100 weeks simulation, the fill rate without government funding was 17%, and with government funding, it was 77% in the presence of 9% shrinkage.

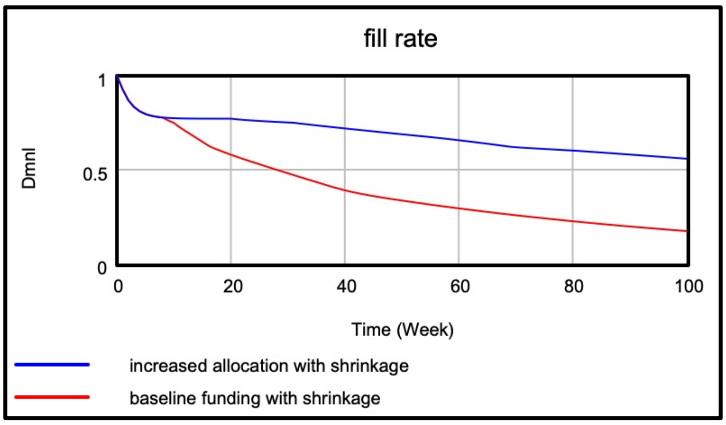


Figure 6.28: Fill rate with increased weekly funding allocation

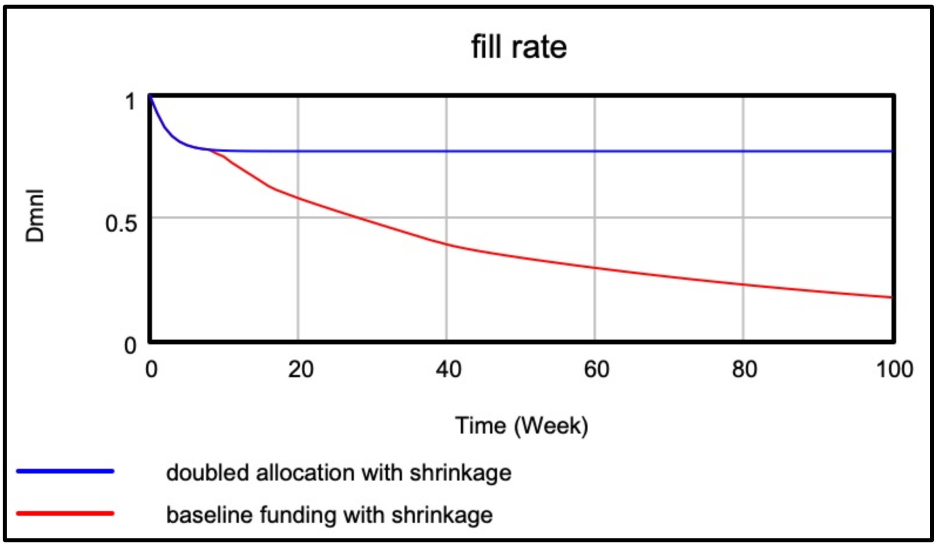


Figure 6.29: Medicine fill rate with doubled weekly funding allocation

Government funding reduced the shrinkage gap by 60% but did not achieve the desired fill rate of 90%. Increasing government funding can help digitalise the supply chain.

6.13.3 Reconciling medicine inventory policy

Expedited information sharing and reducing time delays in reconciliation from eight weeks to two weeks increased the fill rate from 17% to 37% (Figure 6.30). The results showed that increasing the frequency of medicine reconciliation marginally improved the fill rate. When doubled funding of ₦171,428/week was simulated with reduced reconciliation period from 8 weeks to 2 weeks, fill rate increased to 90% at 100 weeks (Figure 6.31).

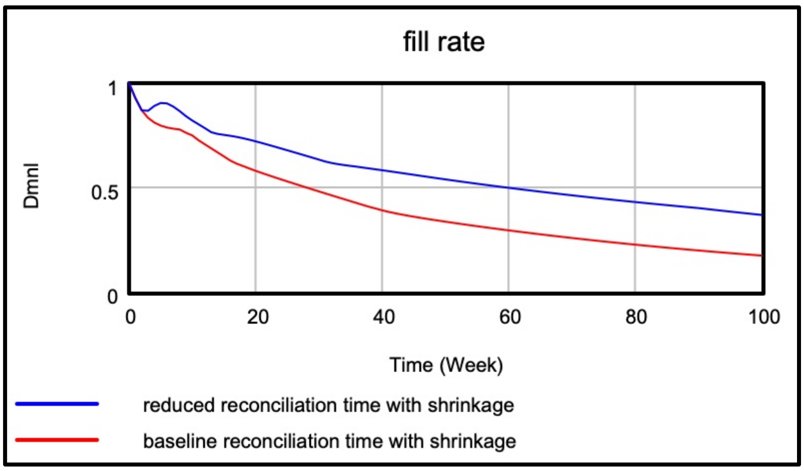


Figure 6.30: Fill rate with two weeks reconciliation period compared with baseline at eight weeks

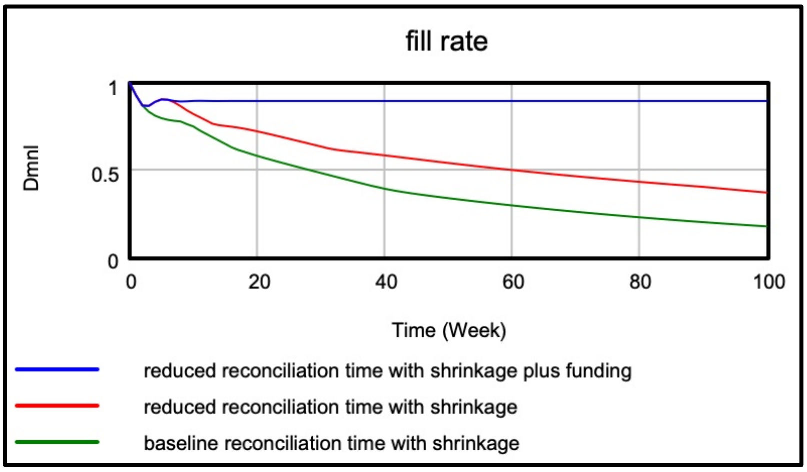


Figure 6.31: Effect of reconciliation time on fill rate with government funding

6.13.4 Policy on payment of accounts receivables

Hospitals sell medicines on credit to other departments within the hospital, also known as internal marketing which accounts for 40% of sales. The baseline rate of accounts receivable payments was 24 weeks with ₦474,355 accounts receivable and a fill rate of 17%. Reducing the payment rate to four weeks reduces receivables to ₦96,874, with an increase in the fill rate to 21% at 100 weeks (Figure 6.32). The desired rate of receivables payment was four weeks, and increasing the rate of payment to four weeks increased the fill rate to 21% (Figure 6.33).

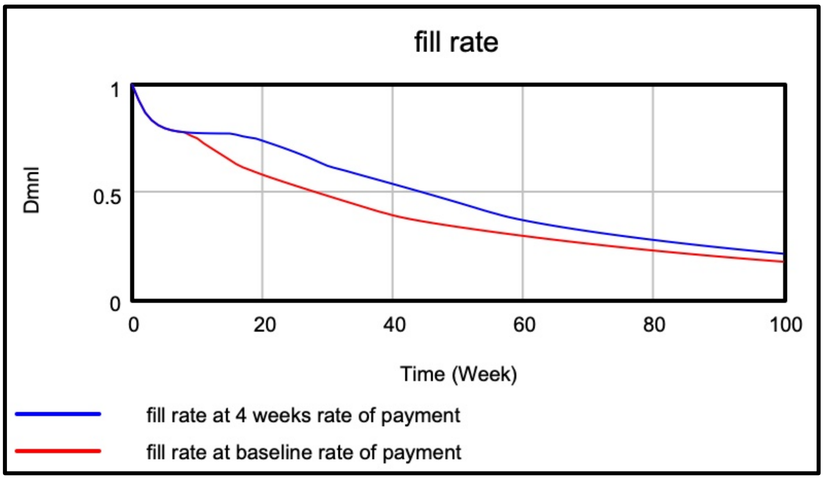


Figure 6.32: Fill rate at baseline and increased rate of receivables payments

Increasing government funding to ₦171,428 per week led to an increased fill rate of 77% which was still below the desired fill rate of 90% (Figure 6.33).

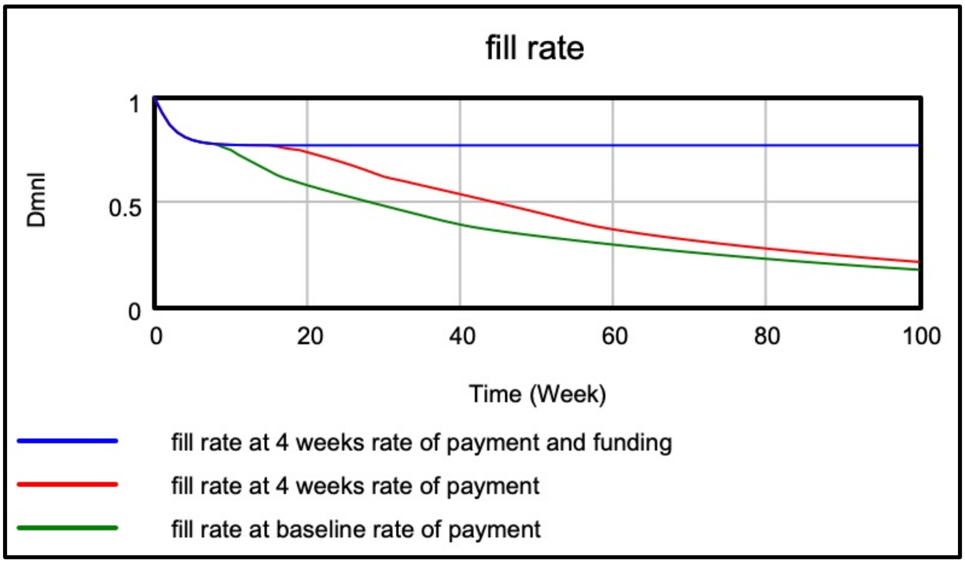


Figure 6.33 fill rate with increased rate of receivables payment and funding

Shortening the reconciliation period from eight to two weeks, with doubled fund allocation, increased the fill rate from 77% to the desired level of 90% (Figure 6.34).

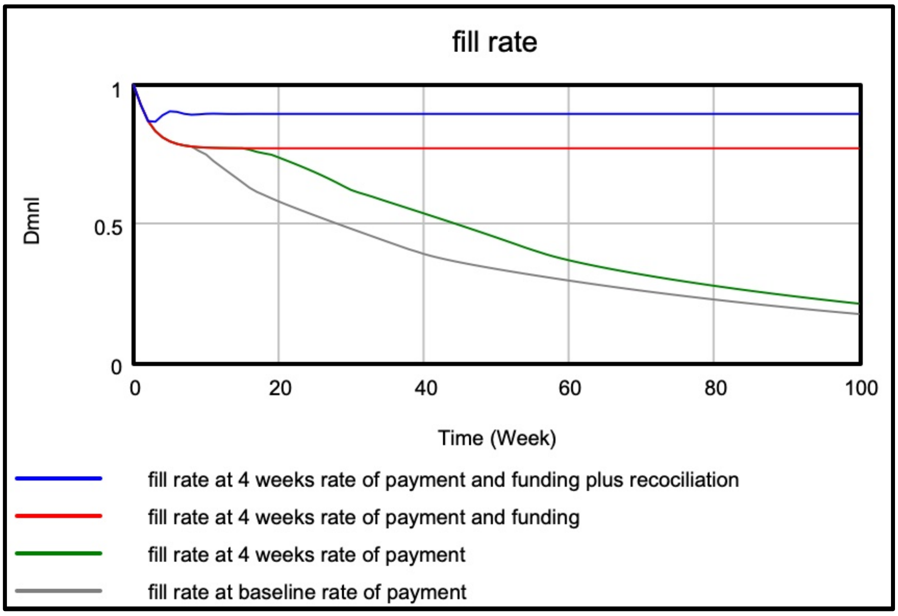


Figure 6.34: fill rate with increased rate of payment and reconciliation

6.13.5 Policy of credit sales of medicines

At baseline, Case A sells 40% of medicines on credit with a 17% fill rate and ₦102,451 cash at bank. Reducing credit sales to zero increased the fill rate to 22% (Figure 6.35) and the cash flow to ₦131,204 (Figure 6.36). Reducing credit sales to zero did not appreciably improve bank cash. Zero credit sales are desired in the DRF program but are unattainable as hospitals sometimes sell to inpatients and other units before getting paid.

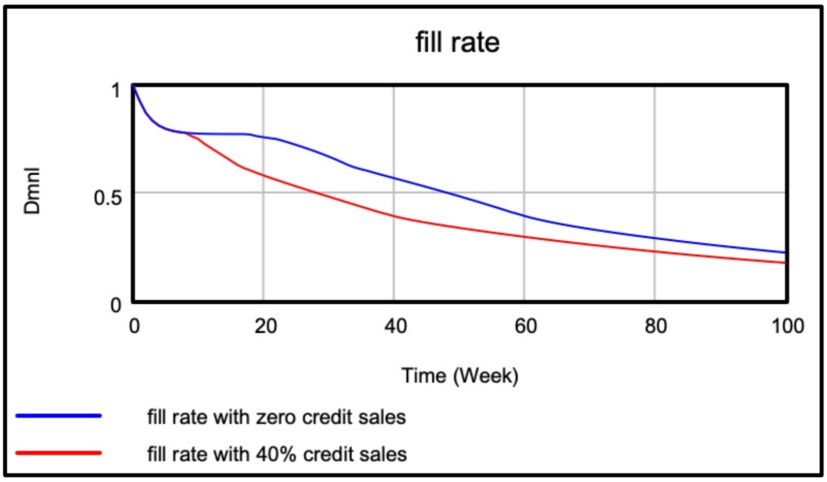


Figure 6.35: Fill rate at baseline compared with at zero percent credit sales

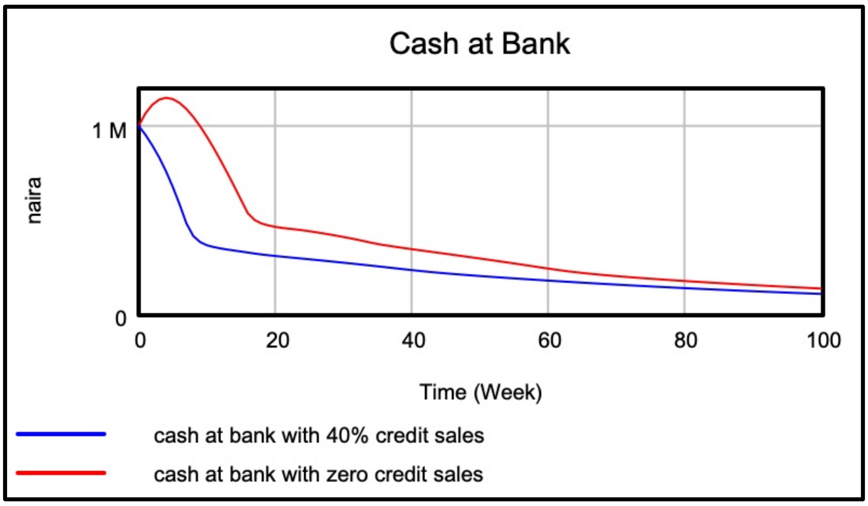


Figure 6.36: Cash at bank at baseline compared with zero credit sales

This result shows that credit sales are not the culprit, as assumed by managers and the old DRF policy based on cash sales only. Reducing credit sales to zero did not appreciably increase the fill rate.

6.13.6 Policy on paying suppliers for medicines delivery

The current DRF policy specifies paying suppliers upon delivery. Paying suppliers were tested at 0.5, 8, and 20 weeks, and the fill rates were 5%, 28%, and 57%, respectively (Figure 6.37**)**. Longer payment terms favour hospitals, as they continue to replenish and sell medicines with increased accounts payables (Figure 6.38**)** and cash at banks **(**Figure 6.39**)**.

The desired time to pay the suppliers for Case A is eight weeks with a fill rate of 28% which is below the desired fill rate of 90%.

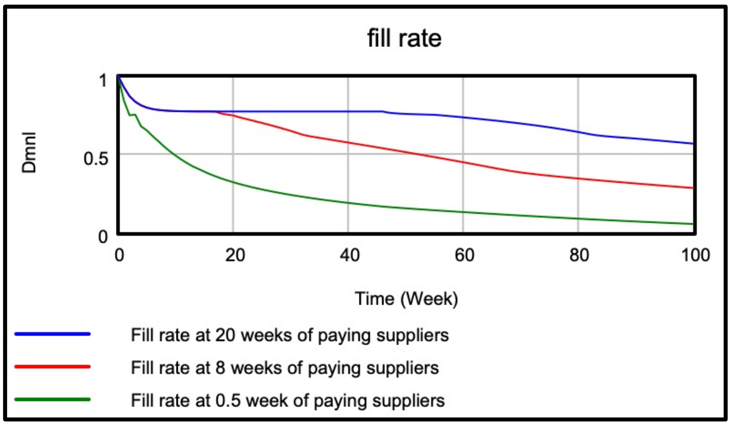


Figure 6.37: Fill rate at time to pay suppliers in 0.5, 8, and 20 weeks

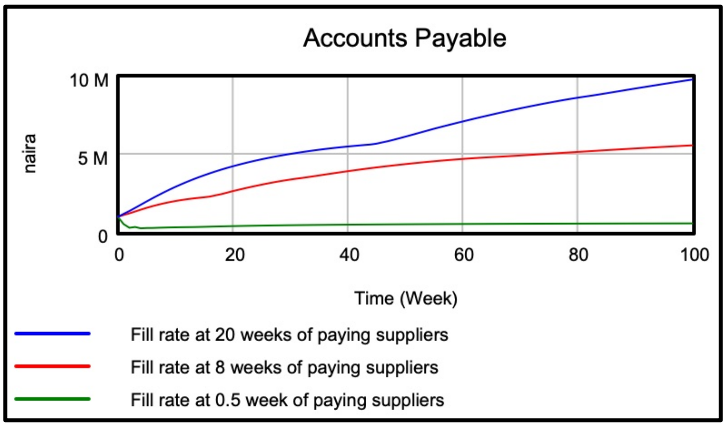


Figure 6.38: Accounts payable at time to pay suppliers in 0.5, 8, and 20 weeks

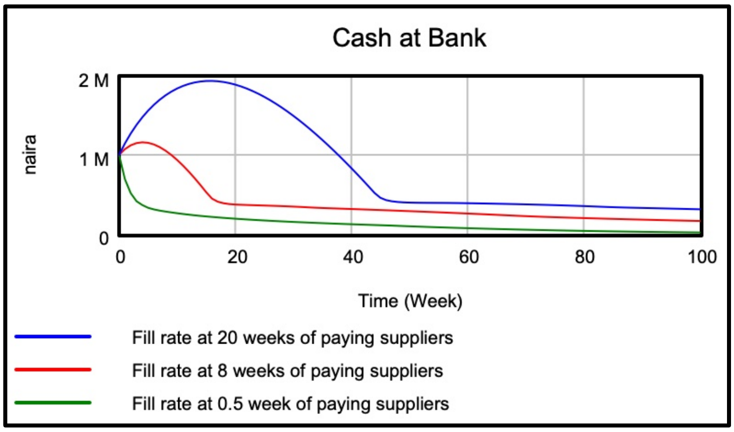


Figure 6.39: Cash at bank at time to pay suppliers in 0.5, 8, and 20 weeks

The credit scores of hospitals depend on the supplier threshold of the customer's credit line. The time to pay suppliers at eight weeks starts with a credit score of one at the beginning of the simulation and ends at 0.2 (Figure 6.40). The decreased credit score was responsible for the below-average fill rate of 36%. Policies that led to higher credit scores increased medicine delivery and fill rate. When the time to reconcile medicine was reduced from eight weeks to two weeks, the credit score did not increase appreciably (Figure 6.41**),** but the fill rate increased from 28% to 52% **(**Figure 6.42**)**.

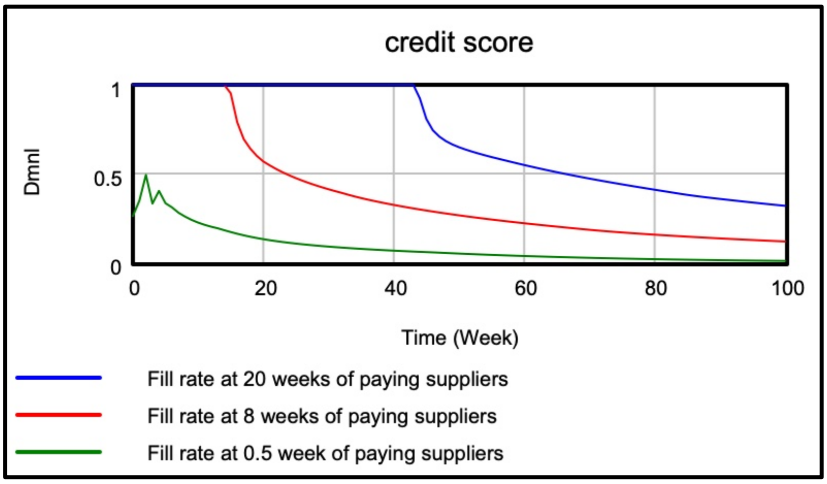


Figure 6.40: Credit score at time to pay to pay suppliers in 0.5, 8, and 20 weeks

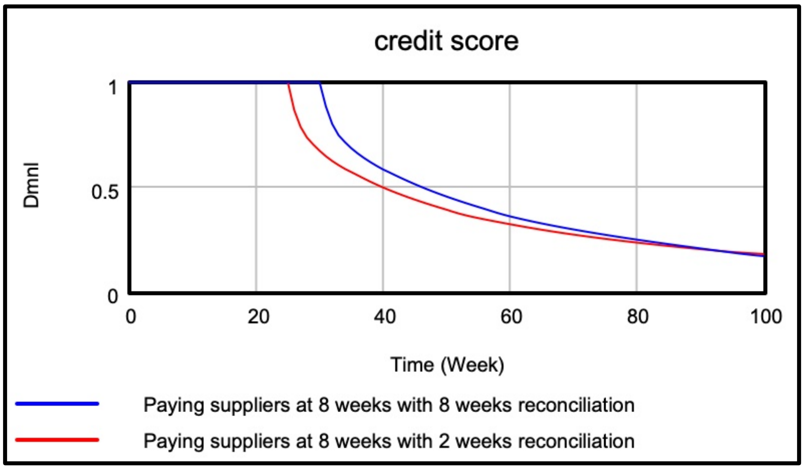


Figure 6.41: Credit score at 8 weeks of paying suppliers and 2 weeks reconciliation

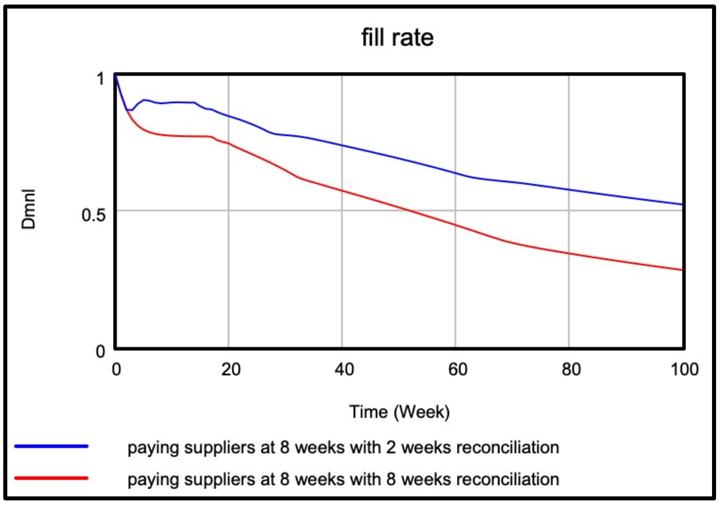


Figure 6.42: Fill rate at 8 weeks of paying suppliers and 2 weeks reconciliation

Although increasing the frequency of reconciliation increased the fill rate, it did not meet the 90% desired fill rate in Case A.

6.14 Conclusion

The reference mode shows that, as the MFR increases, the stockout decreases. An integrated model was tested with Case A to understand the dynamics of improving the medicine availability and fill rate. The model boundaries include hospitals, medicine distributors, and manufacturers. Information for modelling and simulation was obtained from interviews with hospital staff, medicine manufacturers, suppliers, the government, and donors. Variables such as medicine quality, drug abuse, benchmarking, and staff productivity were outside the model boundaries and were not included. The baseline of SC in Case A was measured. Variables were tested for observed effects on shrinkage and expiries, rates of accounts receivable payments, accounts payable, and cash at bank. The effect of scale-up on the fill rate was also tested which showed that the fill rate increased above the desired rate when the shrinkage was blocked. The model was validated at every step by stakeholders using standard system dynamics validation tests. A behaviour reproduction test was conducted, and the integrated model had the same behaviour as the consumption data trends. This model was published for accessibility and policy testing. Policies on shrinkage, government funding, medicine reconciliation, credit sales, paying suppliers, and payment of account receivables were analysed. Achieving an improved MFR requires the development of a combination of policies that align with desired fill rates.

7 DISCUSSIONS OF KEY FINDINGS

7.1 Introduction

This chapter discusses the research findings of this study by considering the aims and objectives of the study and the research questions. The first section addresses research objective 1: to empirically investigate how SCI levels improve medicine availability performance and provide an explanation for the first research question: Does SCI improve medicine availability performance? The second section deals with objective 2, to identify the integration viability of the identified SCs that could affect the availability of medicines, and answer the second research question: How does SCI increase the availability of essential medicines in SCs? The third section focuses on objective 3, to develop a dynamic theory for integrating SCs using a computer simulation model and answers the third question, What type of medicine availability performance does integration improve in essential medicine SCs? This chapter concludes by addressing Objective 4, to validate the dynamic theory to understand the enablers and barriers of medicine availability, while providing the answer to the fourth research question: What are the factors that enable or inhibit the availability of essential medicine SCs?

7.2 Integrated public health supply chain performance

This study aimed to assess the effect of supply chain integration on medicine availability performance from a public health SC perspective. The first question in this study sought to determine whether SCI improves medicine availability in public health SCs to satisfy Objective 1. In reviewing the literature, the integration of SCs was found to include the deployment of internal management practices, information integration, and collaboration with external partner organisations. The research findings showed that public healthcare organisations were more concerned with processes that they perceived to affect their operations and less attuned to challenges faced by suppliers and customers. Of the five cases, only Case A collected real-time data on patients' medication use, giving the SC an edge to sense and respond faster to patients' needs. This could account for the high performance in Case A compared with the other cases. These findings seem to be consistent with other research which found that customer trust improves integration and financial performance (Zhang and Huo, 2013). Another important finding is that the deployment of technology is critical to public health SCs in the provision of medicines to customers. Manual inventory management and procurement processes delay order fulfilment. Public health SCs constitute a majority of the population. Hence, a large number of patients seek healthcare services from hospitals, making it cumbersome to use manual processes to manage supplies. Delays in order fulfilment increase medicine stockouts. This finding supports previous research on information integration which enhances customer performance and supplier collaboration (Wong *et al*., 2015).

The findings on teamwork show that medicine stockouts persist in SCs that operate in silos. Lack of teamwork between the different departments involved in the operations of revolving funds inhibits the availability of medicine. Tensions between procurement teams, pharmacy departments, and accounts foster distrust, thereby derailing the DRF operations. Teamwork competency is necessary to achieve internal integration (Fernando and Wulansari, 2021). Realisation of the desired medicine fill rate requires the cooperation and coordination of all team members. From the findings of this study, it was observed that the five case teams did not fulfil all the criteria necessary for achieving successful project outcomes, as outlined by Shetach (2014), particularly when it comes to shared goals and resolving team tensions. Only Case A had a cross-functional team that worked together using digital platforms to improve medicine delivery and coordination. The remaining four cases did not have digital platforms to enhance their teamwork. This finding shows that it is difficult for public health supply chains to use manual techniques to manage teams, patients, inventories, cash, and medicine delivery. These complicated tasks and various professionals involved in the DRF necessitate the deployment of digital tools to facilitate visibility and coordination across teams. Digital technology supports the execution of demand and supply planning across the SCs. Successful integration requires visibility across the five SCs to improve supply chain responsiveness. Only Case A used a digital platform to collect and make sense of demand information to implement a supply plan. These results are consistent with those of other studies, and suggest that achieving internal SC responsiveness requires visibility and information management competencies (Williams *et al*., 2013).

It is interesting to note that all five cases in this study experienced a continuous loss of sales from medicine stockouts and declining patient trust as their needs were not met. Even Case A, which had higher technology integration, was not able to meet 90% of customer needs. This could be related to a lack of customer and supplier relationship management strategies and tools. Acquiring the right tools and techniques to manage complex healthcare SCs is critical for achieving the desired medicine fill rate performance. Payne and Frow (2005) defined customer relationship management as a strategy that uses data and ICT to co-create value and lasting relationships with customers and stakeholders by utilising the cross-functional competencies of the organisation. SCs that have shifted their focus from products to serving customers using relationship management strategies experience higher profits and customer satisfaction (Bhakane, 2015). Having a holistic view of customer needs supports healthcare practitioners in serving patients and increasing the prescription fill rate (Puschmann and Alt, 2001). In addition, the use of supplier relationships to align customer demand with the supply of medicines has been employed in healthcare organisations. Mettler and Rohner (2009) define supplier relationship management as "a comprehensive approach to enhance cooperation (business relationship level), coordination (process level), and communication (information systems level) between the enterprise and its suppliers in order to continuously improve efficiency and efficacy of collaboration and concurrently enhance quality, security, and innovation". This definition highlights the importance of internal process alignment with external supplier integration in achieving the desired network goals. The study reported increased efficiency in hospital SCs that share supplier information across networks (Mettler and Rohner, 2009). Finally, the findings from this study show that SCI increases medicine fill rate by reducing stockouts. To achieve a 90% fill rate, integrated SCs should consider implementing strategic customer and supplier relationship management.

7.3 Viability of public health supply chains

This section relates to Objective 2 and answers the second question of this study which examines how SCI increases the availability of essential medicines. As mentioned in the literature review, organisations must integrate internally before considering external integration with partners and suppliers (Menon, 2012; Sacristan-Diaz *et al.*, 2018)). This precondition is necessary to increase product, process, and information flows internally and prepare the organisation for external integration. The viability of an organisation to collect information from different departments and process this information to make decisions depends on the internal integration of systems and processes (Schoenherr and Swink, 2012). The current study found that Cases B, C, D, and E had minimal internal integration levels owing to limited digital capability. This digital inadequacy impedes the flow of products, processes, and information, leading to a poor medicine fill rate performance. Only Case A had some visibility in the upstream and downstream information. This could be due to the use of digital technology. A lack of visibility means that DRF operators are unable to acquire the medicines required by patients. Williams *et al*. (2013) define supply chain visibility as "access to high quality information that describes various factors of demand and supply", and argues that internal integration moderates the effect of visibility on performance. This argument aligns with the findings of previous studies (Menon, 2012; Schoenherr and Swink, 2012). The findings of this study show that only Case A has advanced internal integration capabilities and minimal external integration with customers and partners. Case A's external supplier integration needs to be enhanced to achieve a desired medicine fill rate of 90% and above. This can be achieved by adopting advanced supplier and customer management strategies, and by blocking the mismanagement of resources and leakages.

7.4 Dynamic theory of public health supply chains

In line with Objective 3, and to answer the third research question in this study, which sought to identify the types of medicine availability performance derived from SCI. Prior studies have noted the importance of the cash-to-cash cycle, inventory days of supply, and asset turnover in industrial SCs. The key performance indicator for public health SCs is medicine availability which can be determined using the prescription fill rate (WHO, 2008). This study shows that integration with distributors and medicine manufacturers increases the medicine fill rate, and five levels of integration are identified. The levels of integration that improve MFR are internal, external, informational, financial flow, and network integration. These findings support previous studies in which internal, external, and information integration were reported as the foundation of SCI (Prajogo and Olhager, 2012; Ganotakis *et al.*, 2013; Chatzoudes and Chatzoglou, 2015). Another important finding was that financial flow integration improved cash flow and increased MFR. This finding agrees with those of studies that reported an increase in cash flow and decreased cash handling risk from financial integration (Rodríguez-Espíndola *et al.*, 2020). The use of digital cash collection processes increases transparency and trust in a system. DRF programs must focus on cash flow integration to improve the medicine fill rate. A critical finding of this study is the depletion of funds from shrinkage and expiries which can also contribute to delays in paying suppliers. This delay also prevents suppliers from delivering medicines and fulfilling orders, leading to stockouts and decreased MFR. This finding is in line with those of studies that have identified increasing financial resilience to ensure an adequate supply of essential medicines (Duong *et al.*, 2019). Another important finding regarding financial prudence was the absence of budgets in Cases B, C, D, and E. The lack of a budget implies that there is no tracking of supply chain costs and active management of budget deviations. Only Case A had visible budgets and was able to track SC costs regularly. Studies have also underscored the importance of leadership in implementing SCI programs to achieve desired performance (Kang and Moon, 2016; Shee *et al.*, 2018). In this study, inadequate leadership competencies impede the application of supply chain practices and collaboration with stakeholders in Cases B, C, D, and E. These leadership insufficiencies prevent the transfer of knowledge throughout SCs and hinder the ability to solve problems encountered by the operations team. Surprisingly, the adoption of the Treasury Single Account policy by federal government agencies has created tensions in the operations of the DRF programs in Cases B, C, D, and E, with some cases reporting lack of funds for procurement, as suppliers and manufacturers of medicines are not paid for an extended period. These findings defy the logic of TSA as a financial leakage prevention strategy aimed at preventing financial misappropriation and improving transparency (Bashir 2016). One of the objectives of setting up a TSA is to enable the prompt payment of operational expenses incurred by public institutions (Yaker and Pattanayak, 2010). However, the findings from these cases appear to suggest the failure of TSA policy with regard to DRF programs. Interestingly, Case A is exempt from the state's TSA policy and operates a TSA-like accounting system managed by management, with oversight from the government. A possible explanation for this is the consideration of revolving funds as extra-budgetary funds and avoiding the risks of medicine stockouts which can result in the loss of lives. These two reasons have led to the use of separate channels for DRF fund management. This finding corroborates the ideas of Yaker and Pattanayak (2010), who suggest the use of the indirect TSA method for extra-budgetary public health funds using entity-specific accounts for fund management. The use of this indirect TSA method could be responsible for the better DRF fund performance of Case A when compared to other cases that identified financial management as a challenge in operating revolving funds. The above-average fund management performance in Case A can be improved by increasing access to banking and digital infrastructure in remote locations.

7.5 Enablers and barriers of integrated supply chain networks

To achieve Objective 4 and answer the fourth research question, to ascertain the factors that enable or inhibit the availability of medicines. In reviewing the literature, barriers to integration have been identified, including lack of infrastructure, inadequate SC knowledge, financial constraints, human resource practices, and organisational culture. Benevento *et al*. (2023) stated that the barriers to integration in healthcare SCs include "lack of motivation, resistance to change, a noncost-effective mindset, and a lack of initiative from health authorities or dominant players in the ecosystem". Removing these barriers enables integration and improves performance. This study found that the creation of procurement units in Cases B, C, D, and E generated tensions in the system. This decision was a top-down approach, and proper sensitisation to integrate this new cadre of staff into the revolving fund program was inadequate, leading to resistance to change. Resistance to change manifests in the poor MFR of these SCs.

This finding is in agreement with that of Benevento *et al*. (2023), who identified resistance to change as a barrier to integration. The absence of digital infrastructure and incompatible technology systems hinders information sharing within and between organisations. Studies have reported the prohibitive cost of ICT systems required for integration (Sammuel and Kashif, 2013). In this study, ICT systems were only available for Case A. A possible explanation for this might be that the Kaduna State government funds the SC more than federal government-owned hospitals. Interestingly, Case A still grapples with infrastructure problems. This result may be explained by the fact that Case A has over 1000 service delivery points. Connecting all hospitals digitally requires huge investment by the government, considering the remote locations of some hospitals. Financial constraints were observed in all cases, although Case A performed better. Cases B, C, D, and E lacked the digital technology systems and skills to manage their SCs. This result may explain the poor medicine fill rates in all four cases.

In this study, inadequate SC knowledge was revealed by Cases B, D, and E. Although Case C had basic knowledge of inventory management and logistics, Case A had supply chain professionals as staff members with cross-training in different SC areas, such as inventory management, data analytics, demand and supply planning, transport, and logistics. This finding agrees with previous studies that highlight the benefits of SC knowledge in improving operational outcomes, such as order fulfilment in service chains (Wowak *et al.,* 2013). The current study found that the absence of effective management of medicines and funds leads to leakage in the form of expiries, pilferage, and waste. Inefficient handling of inventory is a major source of medicine stockouts. Another risk factor is manual cash handling. The system is exposed to financial risks which, if not mitigated, lead to the failure of the revolving fund. Manual cash collection processes hinder transparency and lead to distrust among the team members. Supply chain relationships are built on trust. The absence of trust limits the adoption of integration practices. Digital platforms can be used to boost trust by entrenching a culture of transparency in SCs. This study identified SCI enablers, namely high-skilled cross-functional teams, digital SC technology, centralised TSA-like accounting system, competent management team, culture of transparency, and network performance structure.

7.6 Conclusion

This section concludes by outlining the four research objectives and answering the four research questions from this study. The answers to the first research question show that SCI improves medicine availability and can be enhanced using digital technology, cross-functional teamwork, and supplier and customer relationship management strategies. The answers to the second question indicate the process of integration which starts internally and ends externally. The viability of the five SCs was determined, and four had limited internal integration capabilities. Only Case A had advanced internal integration and minimal external integration capability. The answers to the third question revealed the medicine fill rate performance achieved with the integration of distributors and medicine manufacturers. The levels of integration that improve MFR were identified: internal, external, information, financial flow, and network integration. Finally, the fourth question was answered by identifying the barriers to SCI which included the absence of effective resource management, inadequate SC knowledge, poor human resource practices, and lack of ICT systems and competencies.

Furthermore, this study started with the background of research situated in five public health supply chains in Kaduna State, where the government has been transforming and integrating SC. The concepts of vertical and horizontal SCI were developed in relation to operational, financial, and network SCP. The stockout rates of essential medicines in Cases A, B, C, D, and E were determined, and the factors responsible were identified as infrastructure and financial management. The mental models of all participants were developed and combined to obtain case mental models. Case-mental models were combined and pruned to develop dynamic conceptual models of SCI. Interpretation analysis and model saturation were determined for each case model and the combined network model. All models were validated using interview analysis and stakeholder validation. The variables, feedbacks, and time delays responsible for medicine stockouts at the network level are determined. Model behaviours that improve fill rates were identified, such as reducing medicine shrinkages and paying suppliers. SCI policies were tested to improve medicine availability and fill rates in Case A. Reducing medicines shrinkage and expiries policy was identified as a prerequisite for successful transformation program scaleup. While increasing government funding appears attractive, the downside is masking supply chain problems that will arise in the future. The government funding loop is an archetype of "shifting the burden" in system dynamics (Kim and Lannon, 1997; Kim, 1999). Instead of resolving the real problems of inventory and financial management policies, SCs choose the escapist approach of 'shifting the burden' to injecting funds.

Finally, combining the perspectives of the system actors is required to improve SCP and MFR. Measuring and managing policy impacts helps address areas of tension and conflict. Apart from the DRF policy, other policies on free medicines, basic healthcare, and insurance have been implemented without policy analysis to determine their effect on other programs such as DRF. This study used a dynamic approach compatible with complex adaptive systems to measure and determine the effects of SCI on MFR and availability. Supply chain management practices that increase team building, visibility, transparency, and communication, establish trust and a culture of continuous improvement. This finding is in line with studies that argue that top management support is needed for SCI (Kang and Moon, 2016; Shee *et al.*, 2018) and that internal cohesion supports the growth of external partnerships (Mofokeng and Chinomona, 2019). Automation of cash collection and payment to suppliers increases confidence in the system, boosting financial performance and fill rates (Zhang *et al.*, 2010; Nandi *et al.*, 2020). Strategic partnerships, collaboration, and negotiations can support manufacturers' relationships with raw material suppliers and access to foreign exchange. Providing visibility to stakeholders such as the government and donors can expand access to global medicine markets and build trust between manufacturers and suppliers. Government interventions can be in the form of reducing tax rates (Bennett and Johnson, 1980) and allocating forex to manufacturers to improve production efficiency and boost local production of medicines (Cravino, 2017). Other instruments for production subsidies can be implemented to increase production capacity. Supplier opportunism arising from information asymmetry can be minimised through strategic partnerships and win-win negotiations. Security of lives and properties is a government function, and partnerships with medicine suppliers can ensure the safety of product delivery. Expanding the access of drone technology to network partners can be achieved through drone sharing and the uberization of medicine deliveries in the network. Some manufacturers and service providers in the network have mature SCs with digital technology platforms that can benefit the entire network through collaboration and strategic partnerships. Building trust with regulatory bodies and process integration to eliminate bottlenecks increases order fulfilment in hospitals.

8 CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE STUDIES

8.1 Introduction

The purpose of the current study was to determine the effect of supply chain integration on medicine availability performance from a public health SC perspective. This aim of this study was achieved using four objectives. The first research objective is to empirically investigate how SCI levels improve medicine availability performance. This objective was achieved by conducting key informant interviews and survey assessments to understand the integration levels and medicine availability performance of the five SCs. The findings of the current study show that SCI improves medicine availability by utilising cross-functional teamwork and digital technology in SC networks. As the level of integration matures, more advanced strategies need to be introduced, namely, customer and supplier relationship management. The second objective was to identify the integration viability of the identified SCs, which could affect the availability of medicines. This objective was achieved by assessing the levels of integration from survey assessments conducted in the five cases. In this study, Cases B, C, D, and E had minimal internal integration levels owing to limited digital capability, while Case A had advanced internal integration and minimal external integration capabilities. The third research objective was to develop a dynamic theory for integrating SCs using a computer simulation model. This objective was achieved by obtaining a list of variables from the quotation analysis conducted on in-depth interviews and used to build a dynamic conceptual model of SCI with the hospital, distributor, and manufacturer echelons of the integrated chain. The levels of integration that improve MFR were identified from the model, namely, internal, external, information, financial flow, and network integration. The fourth objective was to validate the dynamic theory to understand the enablers and barriers to medicine availability. This objective was achieved by building a simulation model of SCI and testing policies to identify barriers to improving the medicine fill rate performance. Barriers to SCI include the absence of effective resource management, inadequate SC knowledge, poor human resource practices, and lack of ICT systems and competencies. The enablers include high-skilled cross-functional teams, digital SC technology, centralised TSA-like accounting systems, competent management teams, culture of transparency, and network performance structure. This study shows that using high-skilled cross-functional teams, digital SC technology, centralised TSA-like accounting systems, competent management teams, a culture of transparency, and network performance orientation improve the medicine fill rate. Starting from internal, information, financial flow, external, and network integration levels, support the medicine availability performance of the network. As the level of integration matures, more advanced strategies need to be introduced, namely, customer and supplier relationship management. The next section outlines the contributions of this study to knowledge and originality.

8.2 Contributions of the study and originality

This study contributes to research in the field of integrating supply chain integration in five ways: theoretical, methodological, empirical, practical, and policy.

8.2.1 Theoretical contribution

The theoretical contributions of this study are as follows:

- This study enriches the SCI theory by developing a dynamic theory for integrating supply chains to improve performance. The design of an integrated network performance-based model expands the existing SCI theories and enables the identification of the levels of integration and performance derived at all levels. The five integration levels identified are internal, external, information, cash flow, and network integrations connected to medicine fill rate performance as a customer-facing indicator to improve medicine availability. The loops driving MFR include production, visibility, trust, and cash flow. Identifying network potentials fills the gap in the literature, as Marques *et al.* (2020) advocated for network studies in healthcare SCs to bring in more voices in tackling healthcare challenges.

- The validated simulation model serves as a structural theory of SCI with system feedback, delays, and accumulations, illustrating the complexity of SCs. The simulation model can be used to integrate all government parallel public health programs, as it considers a wider stakeholder perspective than previous models (Kumar and Kumar, 2015; Bam *et al.*, 2017). The integrated SC model from this study captures the problem dynamics of hospitals, manufacturers, distributors, government, donors, and service providers with a common focus on customer order fulfilment. Expanding the model boundaries to include all the actors within the network contributes to the robustness of the developed theory. The contribution to the system dynamics paradigm crossing strategy used in this study (Figure 8.1) revealed the usefulness of the strategy in supply chain integration research context and answering the research question of this thesis. This shows the potential generalisability and usefulness of the system dynamic integrative methodology in the context of revolving fund supply chain integration, addressing some of the calls for method and theory enrichment (Tomoaia-Cotisel, 2018).

- Contributions to the supply chain management field showed that the use of technology for demand and supply planning with adequate data from hospitals assists EMs supply chains in delivering medicine to patients and improving customer satisfaction. The SC digital analytics skills of staff members prevent stockouts and minimise excess inventory, leading to expiries. This is in line with studies conducted by Hussein *et al.* (2018), van Steenbergen and Mes (2020), and Mbonyinshuti *et al.* (2022) on the use of advanced data management skills to forecast demand and improve medicine availability at the hospitals. The output from the survey assessment showed that SC digital capacity was lacking in Cases B, C, D, and E. Supply chain managers must design knowledge improvement strategies and digital transformation roadmaps for supply chains to catch up with best practices in digital demand planning and electronic procurement. Peer-to-peer learning and knowledge exchange increase the diffusion of skills. The dynamic approach from this study confirmed that capabilities could be pooled and shared within the network.

- This study contributes to the field of supply chain management by developing a supply chain integration and performance measurement model for revolving funds and other public health programmes.

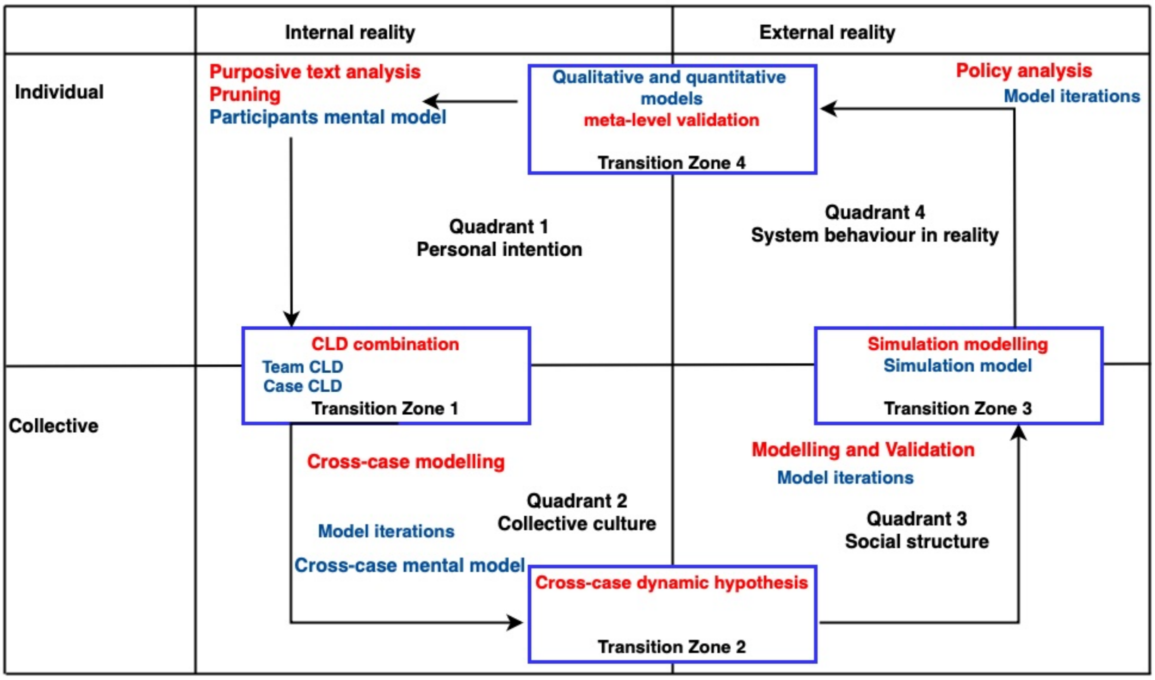


Figure 8.1: Interplay paradigm crossing for system dynamics modelling

The SD methodology starts from individual interviews and ends with meta-level validation using qualitative and quantitative methods. The red text represents methods in all four quadrant. Blue text denotes models developed during the modelling process.

8.2.2 Methodological contribution

The multiple case study method used in this study contributes to the success of this research in understanding SCI dynamics from a systems perspective. This method was useful for data collection from multiple organisations within the SC network. This study contributes to mixed-method research by merging system dynamic approaches with other quantitative approaches, such as group surveys and prescription reviews, to develop a mixed-method framework for SCI. The approach also enriched the system dynamics methodology by adopting a survey method as a precursor to develop qualitative in-depth interviews for model building, and identified the enablers and barriers of integration from the feedback and structure of the ISC model. The surveys captured all the patterns of information and ensured the generalisability of this study. This study was conducted during the covid pandemic and the lessons learned from this study are listed below to guide future research.

- Conducting research during a global pandemic is challenging. Multiple case studies involve seeking approvals to work with different organisations and multiple stakeholders that are very busy and engaged in saving lives. Organisations must be willing to engage in the research and approve participation in surveys and interviews. Obtaining approval from each institution was time-consuming, and delays from bureaucracy were also observed. Therefore, obtaining personal contacts of institutional gatekeepers will help facilitate this process and clarify any concerns raised by the organisations. Starting the engagement process early to provide sufficient time for approval is also important.

- Flexibility is crucial for conducting multiple case study research and system dynamics modelling during major disruptions like the covid pandemic. Adopting a flexible schedule and design are necessary for the success of this study. The physical group survey had to change to an online approach due to changing covid protocols and the restriction of gathering in some cases. Some physical interviews were conducted via telephone and online social media platforms. Group model building was changed to the use of in-depth interviews for the quotation analysis. Hence, being conversant with procedures for online and physical data collection methods helps ensure that data collection is not stalled. Prior practice and preparation with online tools are critical for seamless data collection and for ensuring that participants are comfortable with the selected method. Maintaining flexibility throughout the research process was crucial for the success of this study. Adjusting the study protocol to include COVID rules and regulations, such as using facemasks and hand sanitisers during surveys and interviews, was critical to the success of the current study.

- Working with multiple organisations and stakeholders can be complicated because of interlinked supply chains. This study requires meticulous handling of data by multiple organisations and stakeholders. Having a protocol and framework for data collection and analysis prevents mix-ups in the data and ensures strict adherence to the study design and ethical considerations.

8.8.3 Empirical contribution

By incorporating the perspectives of multiple stakeholders to understand the structure of systems and feedback dynamics, this study provides a unique contribution to healthcare SCI studies. Surveys were conducted with 78 respondents from five case study organisations. Interviews were conducted with 51 participants in five cases. The two methods enriched the broadness and depth of understanding gained from the perspective of various stakeholders within the focal organisations and multiple SC partners. The adoption of organisations with different ownership structures, namely government and federal government-owned SCs, also revealed the nuances in the governance structure of SCs with respect to integration practices and peculiarities in the operations of revolving fund SCs.

8.2.4 Practical contribution

The dashboard developed in this study improved the understanding of stakeholders by enabling visualisation and engagement with the system regarding the operations of integrated SCs and its effects on the fill rate. The use of cloud-based technology for the dashboard revealed the benefits of the technology in the system and allowed real-time one-on-one interaction with the system. The dashboard also allowed the engagement of multiple stakeholders working with the system simultaneously, mimicking real-time operations and facilitating learning on integrated SCs. In addition, this study identified enablers of and barriers to SCI which can help managers adopt strategies to enhance integration with their partners. Some SCI barriers include lack of trust at the internal, external, and network levels. Lack of access to innovative technologies for manufacturers, such as drone delivery which reduces travel time and can be used to overcome challenges with bad road networks and security of lives and properties. Inadequate SC knowledge and digital skills prevent SCI readiness in public health organisations. Insufficient relational maturity to manage collaborative networks. An inward-facing performance culture of public healthcare SCs ensures that each program is designed to fail by focusing on the internal goals of the organisation. SCI enablers include the adoption of a network-oriented performance culture to capture the diversity of partners' perspectives and co-create solutions for improvement. Acquisition of SC knowledge and digital SC capability helps the network handle huge volumes of patients' needs efficiently working with close partners. Investment in ICT infrastructure with network cost-sharing agreements. Adoption of inventory management best practices using digital platforms for transparency and accuracy. Access to advanced technologies, such as WMS, ERP, control towers, IoT, and automation, helps with visibility network management. Relational capital is critical for stakeholder management and for navigating SC relationships. Buidling relational capacity will help SCs work better as a network. Finally, this study will encourage researchers and practitioners to embrace a performance-driven approach and benchmark public health SCs for improved service delivery.

8.2.5 Policy contribution

This study contributes to the policy analysis and implementation of revolving fund SCs by enabling supply chain managers, medicine manufacturers, suppliers, third-party logistics service providers, and donors to visualise, reframe, and engage with policymakers to resolve bottlenecks in the public health SC to improve medicine availability. The six policies analysed in this study on shrinkage, government allocation, reconciling inventory, credit sales, payment of accounts receivables, and payables contribute to policies involving multiple stakeholders across the SC network.

- The integration viability of the five SCs helps policymakers develop the adoption strategy for Case A as an anchor for integration across the state. Sharing and deployment of SC knowledge, pharma-grade infrastructure, IT capacity, digital platforms, drone partnerships, WMS, ERP for network use. The modalities of implementation between state and federal governments must adopt a collaborative asset and risk-sharing network strategy.

- This study will guide donor agencies' policies towards impactful investments in revolving fund SCs by leveraging the outcomes of this study to integrate parallel supply chains and reduce wastage in the system. Efficient DRF systems will unlock more funding to procure essential medicines for wider population coverage and to meet patients' needs.

- The policies will guide future partnerships between stakeholders on the pitfalls of revolving fund SCs and help in designing better policies for successful program implementation.

- The outcome of this study will guide the government in reviewing other SC policies that create tensions with the DRF program for harmonisation, such as NHIS, BHCPF, and TSA.

8.3 Limitations of the research

The current study had several limitations.

- The research used five public health SCs owned by the state and federal government located in the Kaduna state. All SCs operated on the essential medicine DRF. However, The study did not include public health SCs outside Kaduna State. Thus, it is necessary to test the model in other states.

- Although the developed policies were tested in the integrated SC, there is a need to test policy implementation through engagement with the government and external stakeholders to integrate the leverage areas identified in this study, such as procurement, knowledge sharing, and technology sharing.

- This study engaged multiple stakeholders during interviews for model building, and customers were represented in the model by internal and external customers, such as hospitals and donors. Nevertheless, there is a need to engage end users to obtain their perceptions of the system when accessing essential medicines.

- This research explored essential medicine DRF supply chains, and other public health programs and government policies were mentioned in interviews with stakeholders. There is a need to further investigate the tensions between DRF and other programs, such as free medicine programs, the National Health Insurance Scheme (NHIS), Treasury Single Account, and the Basic Health Care Provision Fund, to improve medicine availability.

- An organisational network lens was used to examine the DRF medicine SC. Ensuring medicine accessibility to end users' needs to be explored in future studies. There is a need to examine the accessibility of DRF medicine from the patient's perspective.

- The key performance indicator used in this research was the medicine fill rate, which is the WHO standard for measuring medicine availability in healthcare SCs. There is a need to consider other performance indicators that can enrich the integration of SCs to ensure accessibility to medicines.

- This study adopted a quotation analysis and stakeholder engagement for model building because of constraints from covid restrictions. Multiple interviews with various stakeholders enriched the model-building process. However, future studies can engage in group modelling techniques where all stakeholders can participate in model building to provide a learning opportunity across the network.

- This study was conducted during the covid pandemic which was accompanied by extreme stockouts of medicines and hospital commodities. Essential medicine SCs were assessed by engaging multiple institutions and stakeholders across the three echelons of manufacturers, distributors, service providers, donors, and hospitals. Nonetheless, it is crucial to examine market forces that can exacerbate medicine stockouts during extreme disruptions, as witnessed during the pandemic.

8.4 Recommendations

The five SCs can be integrated using resource-pooling and sharing strategies. Case A has an abundant SC capacity, which can be shared and leveraged by the remaining SCs. The increased demand generated by Case A scale-up to all health institutions creates opportunities for pooling demand from other hospitals to benefit from scale and scope economies in procurement. This is in line with studies on SC management practices that support collaborative planning and replenishment (Sundram *et al.*, 2016). Leveraging digital platform capabilities present in the network means that Cases B, C, D, and E can immediately begin to migrate from manual operations to digitalisation of processes with minimal setup costs for the government and stakeholders. Electronic procurement already in practice in Case A can be expanded to include other SCs (Chang *et al.*, 2013; Pattanayak and Punyatoya, 2020). Building knowledge-sharing networks enables the knowledge flow of SC improvement strategies. The structure of SCs needs to be adapted in line with agile organisations. The hierarchical command and control structure prevents the flow of information, leading to time delays and medicine stockouts. SC and human resource management practices are instrumental in improving performance (Menon, 2012; Sundram *et al.*, 2016; Tarifa-Fernandez *et al.*, 2019). Successful network integration must be devoid of bureaucracies in the operations at all levels. All organisations are owned by the government, and there must be a new structure for the DRF program to align with the new government policies on TSA, the National Health Insurance Scheme, the Basic Healthcare Provision Fund, free medicine programs, and other policies that create tensions in the DRF. Introducing procurement units in hospitals should be accompanied by changes in management strategies and clear roles and responsibilities. Currently, there is no motivation for behavioural change among staff, and shifting to performance-based human resource management improves staff performance output.

Fostering trust, accountability, and transparency enabled by technology increases collaboration with external stakeholders, unlocking goodwill, and funding from donors and philanthropists. The use of logistics service provider for hospital medicines delivery can be shared with medicines suppliers to pool risks and minimise delays within the network as noted by Sato *et al.*(2021). Storage facilities must be upgraded to safeguard medicine quality and prevent deterioration, particularly at high temperatures in Africa. Medicine storage can be pooled at the subnational level using Case A's pharmagrade warehouse and the cost-sharing mechanism between partners (Gils *et al.*, 2018). Teambuilding activities can be deployed to increase internal teamwork and realign teams toward shared goals (Hataminezhad, 2019). Policymakers and top management of healthcare SCs must carefully study all other policies related to the revolving fund policy and resolve conflicts and tensions that prevent successful implementation. A lack of commitment on the part of focal firms leads to failure of integration and erosion of SCI (Azoulay *et al.*, 2010; Ramirez *et al.*, 2021). Factors that disabled the integration of SCs include the financial instability of organisations in the network and policy misalignment of healthcare programs such as free medicine programs, basic healthcare provision funds, and national healthcare insurance programs. Combining incompatible procurement policies for the same products and suppliers when the same EMs are procured using emergency procurement and competitive bidding. Discordant supply chain relationships in medicine procurement using transactional relationships and framework contracts for the same products. Uncertainties in the relationship between hospitals and suppliers lead to opportunism. The inability to enforce contracts among partners erodes commitment and trust leading to unstable relationships (Tsanos and Zografos, 2016; Feriyanto *et al.*, 2019; Yeh *et al.*, 2020). Conflicting performance management goals between government and private sector performance-driven approaches promotes distrust, and inadequate contract management erodes commitment, as suppliers will not deliver products when buyers do not meet their obligations. Stakeholder trust is the foundation of network integration. Staff performance is delinked from network goals, even though primary, secondary, and tertiary healthcare institutions are connected in theory. The reality shown in this study is the lack of collaboration among the three levels of care in the provision of essential medicines. Collaboration among stakeholders is required to achieve MFR, as demonstrated in previous studies (Zander *et al.*, 2016; Zhang *et al.*, 2016; Oh *et al.*, 2020). SCs get trapped in the complacency trap as salaries are not paid based on staff performance, and customers suffer from poor quality services with delays leading to failed treatment and loss of life. The bailout trap of hospital SCs, as managers anticipate funding from the government or donors, prevents innovation. The two traps of complacency and bailout are responsible for SCs becoming stuck in the arrested development phase. To escape this phase, SCs must leverage capacities within the network. Knowledge-sharing capacity among partners improves network performance (Sangari *et al.*, 2015; Al Dweiri and Isa, 2019). The results of this study support the theoretical proposition that medicine availability only increases in organisations with network integration of their SCs and not just internal integration to improve medicine availability. Finally, government firms have a different performance focus compared to their private partners; redesigning public sector staff incentives towards performance will align with private sector goals and ensure mutual commitment to serving patients (Bennett and Johnson, 1980). SCI can only be successful with the restructuring of public healthcare supply chains using performance-based human resource management to achieve organisational and network goals.

8.5 Future research

This research focused on EMs revolving fund programs which are government-driven, and SC researchers need to examine the leverage points for other donor-supported SCs to minimise wastage and duplication of effort. There is also a need to examine the cost of integration to design a means of cost sharing between partners and determine the extent and cost of information integration. The drone logistics services deployed in Case A need to be explored to determine the viability of sharing this service between partners by assessing the cost trade-offs of drone medicine delivery and the network design of partner SCs. To understand if adopting a network delivery strategy affects the network design of partner SCs, and to what extent? This study focused on revolving fund SCs, it will be expedient in exploring how free medicines and other sources of essential medicines, such as insurance programs and basic healthcare programs, fit into the dynamic SCI theory. The integrated model did not consider the dynamics of medicine prices and raw material sourcing for manufacturers, and future studies can help determine if the network is getting the best price for value. The forex challenges mentioned by suppliers are not captured in the model, and it is important to examine the impact of these market forces on access to medicines for end users. Security was also highlighted as a challenge in medicine delivery, and the rising insecurity in Nigeria and Africa will benefit from studies that evaluate the impact of insecurity on last mile delivery of medicines and propose strategies for obtaining products for patients in remote locations. This study identified how different levels of stakeholders can work together to improve availability and fill rate performance. Further studies should be conducted on patient service levels and satisfaction.

The use of fill rate as a performance measure was based on the data sources available in the SCs. Only one case adopted performance measurement. Exploring other performance measures under the reliability and agility categories from healthcare SCs with adequate data will help in understanding a holistic approach to SCI in public healthcare SCs.

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APPENDIX I: RESEARCH PUBLICATIONS AND PRESENTATIONS

Peer-reviewed research publications

Abdulkadir, R., Matellini, D. B., Jenkinson, I. D., Pyne, R. and Nguyen, T. T. (2023) 'Assessing performance using maturity model: a multiple case study of public health supply chains in Nigeria', *Journal of Humanitarian Logistics and Supply Chain Management*, ahead-of-print(ahead-of-print).

Conference papers and posters

2023 Journal article titled **'**A dynamic modelling approach to reduce revolving fund medicine stockouts in Nigeria' (Abdulkadir R. *et al...*) (Submitted for review)

2023 Conference paper titled 'Shifting the Burden of Essential Medicine Stockouts in Nigerian Public Healthcare Supply Chains' at the *International System Dynamics Conference,* System Dynamics Society, Chicago, United State of America, 23rd - 27th July 2023. (Abdulkadir R. *et al...*) (Submitted for review)

Presenter: Ramatu Abdulkadir

2023 Conference paper presentation titled 'The dynamics of supply chain relationships on medicine availability: a case of Kaduna essential medicine delivery' at the *Faculty Research Conference*, Liverpool John Moores University, Liverpool, United Kingdom, 24th May 2023. (Abdulkadir R. *et al...*) (Submitted for review)

Presenter: Ramatu Abdulkadir

2022 Conference paper presentation titled 'Medicine Availability and the Dynamics of Revolving Fund Delivery Channels in Nigeria' at the *4th African Conference on Operations and Supply Chain Management*, 27th July 2022, Nairobi, Kenya. (Abdulkadir R. *et al...*)

Presenter: Ramatu Abdulkadir

2022 Poster presentation titled 'The Dynamics of Supply Chain Integration on Medicines Availability in Nigeria' at the *International System Dynamics Conference*, 18th July 2022, Frankfurt, Germany. (Abdulkadir R. *et al...*)

Presenter: Ramatu Abdulkadir

2022 Poster presentation titled 'Dynamic Integration of Supply Chains to Improve Medicine Availability in Nigerian Hospitals' at the *Faculty Research Day*, Liverpool John Moores University, United Kingdom, 29th June 2022. (Abdulkadir R. *et al...*)

Presenter: Ramatu Abdulkadir

2021 Conference paper presentation titled 'Assessing Performance Using Maturity Model: A Case Study of Public Health Supply Chains in Nigeria' at the *3rd Annual African*

Conference on Operations and Supply Chain Management, 29th September 2021, Kigali, Rwanda. (Abdulkadir R. *et al...*)

Presenter: Ramatu Abdulkadir (Best Presenter Award)

2021 Forge: Championing supplier diversity. *Procurement Foundry Virtual Conference*, 25th February 2021. Moderator: Pavel Subrt Speakers: **Ramatu Abdulkadir**, Martin Mirimo, Azuka Okeke, John Everett

Podcast

The Top 3 Challenges for Supply Chains in Africa with Ramatu Abdulkadir on 15th November 2021. *Supply Chain Now*. Host: Scott Luton, Jenny Froome. **Presenter: Ramatu Abdulkadir**

Strengthening Nigeria's Healthcare Supply Chains on 5th July 2021. *Supply Chain Now*.
Host: Scott Luton **Presenter: Ramatu Abdulkadir**

Supply Chain Strategies: Managing Change in Public Health Supply Chain During Covid-19 Pandemic. 15th July 2020. *Bicara Supply Chain*. Host: Nurhadi **Presenter: Ramatu Abdulkadir**

Webinar

Leading change in public health supply chains in Nigeria, 13th august 2020. *Chartered Institute of Procurement & Supply Nigeria*. Host: Salisu Uba, Co-host and moderator: Daniel Etameta. Presenter: **Ramatu Abdulkadir**

Improving global health forecasting: Data Science, Advanced algorithms & partnerships, centre for global development, 13th November 2020. *Center for Global Development*.
Presenters: Mamadou Samba, Alma Crumm Golden, Alessandro de Luca, **Ramatu Abdulkadir**, Glenn Milano. Moderator: Prashant Yadav

Oral presentation

Taking Stock of Developing your Supply Chain Leaders, 23rd November 2020. *SAPICS.*
Moderator: Hekkie van der Westhuizen
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APPENDIX II: KEY INFORMANT INTERVIEW PROTOCOL

Table 1: Key informant interview protocol

No	Key informant interview questions
1	How does your organization carryout demand forecasting of medicines?
2	How does your organization carryout procurement of medicines?
3	How does your organization carryout warehousing of medicines?
4	How does your organization carryout inventory management of medicines?
5	How does your organization carryout delivery of medicines to patients?
6	Which departments/units are responsible for making medicines available to end-users?
7	Has your organization experienced stock out of medicines?
8	How do you manage stockout of essential medicines?

APPENDIX III: PRESCRIPTION REVIEW PROTOCOL

Prescription review protocol

1. Which of the medicines from each class of the essential medicine has the highest consumption rate in your hospital?
2. What is your source of evidence?
3. How did you determine the consumption rate of medicines?

Example of sources of evidence for prescription review:

1. Prescription review
2. Clinical case review
3. Procurement data
4. Others – Please specify

Please feel free to add any comment:

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APPENDIX IV: SAMPLE QUESTIONNAIRE FOR PERFORMANCE MEASUREMENT

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Global Health Supply Chain Maturity Model v8.0

Please complete questions in all 20 Maturity Model categories. Each category appears on a separate page. As you complete a category, your responses will automatically be saved in the event you inadvertently exit the assessment website or lose your internet connection.

To save a copy of your responses, please follow the instructions on the last page of the questionnaire.

Assessment Profile

1. Please include the following information:
   - Country and Region/State/Country: (required) ______________________________
   - District/Organization/Other: (optional) ______________________________
   - Date of Completion: ______________________________
   - Names of Individuals or Team Completing the Evaluation: ______________________________
   - Type of Organization (Private, Public, or NGO) ______________________________
   - Is this assessment supported by a donor organization?
     - O No
     - O Yes (please name donor)
   - Registration: (choose one) — If you wish to enter both an email address and a Registration code, please record the Registration code in the *District/Organization/Other* field above.
     - O Registration code: ______________
     - O Self-assessment: (For self-assessment, you must provide an email address below) ______________

2. Please indicate the commodity type for which the assessment is being completed. (choose one) — If you are completing an assessment for COVID-19, please select *Other* and write in *COVID-19*.
   - O Family Planning
   - O Reproductive Health
   - O Essential Medicines
   - O Vaccines
   - O HIV
   - O Malaria
   - O Tuberculosis
   - O Integrated Commodities (please describe the commodities): ______________________________
   - O Other (please specify): ______________________________

3. Which supply-chain stakeholders are represented in the assessment? (choose all that apply)
   - ☐ National (identify by name): ______________________________
   - ☐ State (identify by name): ______________________________
   - ☐ County (identify by name): ______________________________
   - ☐ Sub-county/Community (identify by name): ______________________________
   - ☐ Site (identify by name): ______________________________
   - ☐ Other (please specify): ______________________________

4. How many assessments have been conducted previously with this same scope and supply chain? (choose one)

- ○ 0
- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5
- ○ More than 5
- ○ Don't know

5. What is the primary source of the information for this assessment? (choose one)

- ○ First-hand experience
- ○ First-hand experience and second-hand information (from another person or information system)
- ○ Second-hand information (from another person or information system)

Service Delivery Point (SDP)/Health Facility (HF)

I. SDP/HF Visibility

Service Delivery Points/Health Facilities generate data regarding the inventory levels and consumption of product on site. As maturity increases, the supply chain increasingly receives real-time data from SDPs/HFs that feeds into a broader supply-chain digital platform.

Objective: Improve the visibility and tracking of inventory at the SDP/HF.

6. Please describe the visibility of inventory and consumption from the facility(ies): (choose one)

- ○ Limited visibility to inventory and consumption at facilities (quarterly)
- ○ Some visibility to inventory and consumption at some facilities, monthly (minimum of 80% of facilities)
- ○ Visibility to inventory and consumption at most facilities, twice per month (minimum of 80% of facilities)
- ○ Some digital visibility (near real time; 1 week or faster) to inventory and consumption at most facilities (minimum of 90% of facilities)
- ○ Digital visibility (near real time) to inventory and consumption at all facilities (100% of facilities)
- ○ Not applicable
- ○ Don't know

7. Please describe the visibility of upstream supply-chain inventory information to the facility(ies): (choose one)

- ○ No visibility of upstream supply-chain inventory information
- ○ Upstream supply-chain information is rarely available and only if requested
- ○ Some upstream supply-chain information provided to facilities (about warehouse/store inventory, upcoming shipments, health programs)
- ○ Upstream supply-chain information provided to all facilities
- ○ Automated upstream supply-chain information process connects to supply-chain digital platform
- ○ Not applicable
- ○ Don't know

8. How is inventory information within the facility(ies) shared with supply-chain partners?(choose one)

- ○ Inventory information is not shared with supply-chain partners
- ○ Some inventory information is shared verbally, manually, or handwritten with supply-chain partners
- ○ Inventory information is shared electronically with supply-chain partners
- ○ Data connected to larger supply-chain digital platform or national logistics management information system
- ○ Data connected to larger supply-chain digital platform or national logistics management information system with real-time dashboards for decision-making
- ○ Not applicable
- ○ Don't know

9. Which of the following are constraints that prevent improvement of inventory visibility at facilities? (choose all that apply)

- ☐ Human resources
- ☐ Improvement-process knowledge
- ☐ Enabling technologies
- ☐ Leadership/guidance
- ☐ National guidelines
- ☐ Funding
- ☐ Infrastructure
- ☐ Government support
- ☐ No public/private collaboration
- ☐ Other (please specify): ____
- ☐ No constraints
- ☐ Not applicable
- ☐ Don't know

Comments/notes for this category:

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II. SDP/HF Inventory Management

Inventory in the facilities is segmented into simple product categories to improve data (e.g., quantities, expiration dates, stockouts) and provide a clearer sense of what products are needed. As maturity increases, regular audits are conducted to ensure accurate product levels and adherence to policies to maintain appropriate stock levels.

Objective: Standardize inventory-handling practices at SDP/HF to ensure that optimal levels of inventory are always available.

10. How are inventory levels within the facility(ies) established?(choose one)
   - ○ No process to establish inventory levels
   - ○ Staff react to depleted inventory and stockouts
   - ○ Policy/guidelines are in place to inform how much inventory should be kept in the facility(ies)
   - ○ Inventory segmentation used to calculate stocking levels (monthly)
   - ○ Dynamic segmentation used to calculate stocking levels (daily)
   - ○ Not applicable
   - ○ Don't know

11. How frequently are physical stock counts conducted within the facility(ies)? (choose one)
   - ○ No physical stock counts
   - ○ Random physical stock counts
   - ○ Regular physical stock counts conducted (at least quarterly)
   - ○ Regular physical stock counts conducted (monthly)
   - ○ Frequency of physical counts dynamically determined by inventory control system
   - ○ Not applicable
   - ○ Don't know

12. Which of the following are constraints that prevent improvement of inventory management at facilities? (choose all that apply)
   - ☐ Human resources
   - ☐ Improvement-process knowledge
   - ☐ Enabling technologies
   - ☐ Leadership/guidance
   - ☐ National guidelines
   - ☐ Funding
   - ☐ Infrastructure
   - ☐ Government support
   - ☐ No public/private collaboration
   - ☐ Other (please specify): ____
   - ☐ No constraints
   - ☐ Not applicable
   - ☐ Don't know

Comments/notes for this category:

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III. SDP/HF Order Management

The facility can determine the need to order more inventory, identify that an order is based on inventory policies, and execute the order in a timely manner. As maturity increases, orders are created within a broader supply-chain digital platform on demand.

Objective: Execute order management at the SDP/HF in relation to inbound orders, outbound inventory, real-time demand, and SDP/HF budget.

13. How do/does the facility(ies) determine the need to order inventory? (choose one)
   - No process to determine the need to order inventory
   - Manual/visual process used to determine the need to order inventory
   - Ordering of inventory is based on inventory policies, guidelines, and/or SOPs
   - Digital order management process is in place, or a process to digitize within 1 day exists
   - Orders are created on demand through consumption or demand calculated by an electronic inventory management system
   - Not applicable
   - Don't know

14. How is the order quantity for the facility(ies) determined? (choose one)
   - No process to determine order quantity
   - Visual review of inventory determines order quantity for the facility(ies)
   - Automated ordering for the facility(ies) based on inventory management strategy
   - Automated ordering that accounts for orders already placed, but not received
   - Order management is connected to the supply-chain digital platform that recommends resupply based on demand and consumption
   - Not applicable
   - Don't know

15. How are orders checked against the budget of the facility(ies) for the order? (choose one)
   - Orders are not checked against the budget
   - Budget constraints are sometimes recognized and can affect ordering
   - Order amount authorized by those with budget information
   - Order amount considers the facility's (ies') budget
   - Order amount electronically checked in real time against the facility's (ies') budget
   - Not applicable
   - Don't know

16. Which of the following are constraints that prevent improvement of order management at facilities? (choose all that apply)

- ☐ Human resources
- ☐ Improvement-process knowledge
- ☐ Enabling technologies
- ☐ Leadership/guidance
- ☐ National guidelines
- ☐ Funding
- ☐ Infrastructure
- ☐ Government support
- ☐ No public/private collaboration
- ☐ Other (please specify): ______________________________
- ☐ No constraints
- ☐ Not applicable
- ☐ Don't know

Comments/notes for this category:

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Warehouse/Store

IV. Warehouse/Store Visibility

Within supply-chain warehouse(s)/store(s), all products, inventory levels, and orders can be identified whether they are on the shelf, inbound, or outbound. As maturity increases. the supply chain has a Warehouse Management System (WMS) that is connected to a broader supply-chain platform, which allows the warehouse/store to define specific inventory level rules.

Objective: Improve the visibility and tracking of inventory within the warehouse(s)/store(s).

17. How is product located at the warehouse(s)/store(s)? (choose one)

- ○ Difficult and time-consuming to locate specific product within warehouse(s)/store(s)
- ○ Warehouse(s)/store(s) is arranged to ease identifying the location of specific product
- ○ Manual tools available to track product in warehouse(s)/store(s)
- ○ Electronic WMS with batch and bin tracking used to track product in warehouse(s)/store(s)
- ○ Real-time tracking and visibility of product in warehouse(s)/store(s)
- ○ Not applicable
- ○ Don't know

18. Describe the ability to identify order status within the warehouse(s)/store(s)? (choose one)

- ○ Not able to identify order status
- ○ Difficult to identify order status
- ○ Ability to track order status
- ○ Visibility to incoming and outgoing inventory (past and future)
- ○ Visibility to incoming and outgoing inventory (past and future) through an inventory management system with real-time, event-driven decision-making or real-time dashboards
- ○ Not applicable
- ○ Don't know

19. How is inventory information in the warehouse(s)/store(s) shared with others in the supply chain? (choose one)

- ○ Inventory information is not shared with the supply chain
- ○ Some inventory information shared upon request
- ○ Inventory information sent to supply chain periodically
- ○ WMS connected to supply-chain digital platform/LMIS (logistics management and information system)
- ○ WMS connected to supply-chain digital platform with what-if analysis and real-time, event-driven decision-making
- ○ Not applicable
- ○ Don't know

20. Which of the following currently are constraints that prevent improvement of visibility at warehouse(s)/store(s)? (choose all that apply)

- ☐ Human resources
- ☐ Improvement-process knowledge
- ☐ Enabling technologies
- ☐ Leadership/guidance
- ☐ National guidelines
- ☐ Funding
- ☐ Infrastructure
- ☐ Government support
- ☐ No public/private collaboration
- ☐ Other (please specify): ____
- ☐ No constraints
- ☐ Not applicable
- ☐ Don't know

Comments/notes for this category:

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V. Warehouse/Store Inventory Management

At the warehouse/store level, there is a defined amount of inventory of each product that should be maintained, based on demand. These levels are not fixed and should be updated on a regular basis. As maturity increases, regular audits are conducted to ensure accurate product levels and adherence to policies to maintain appropriate stocking levels.

Objective: Standardize inventory-handling practices at the warehouse(s)/store(s) to ensure optimal levels of inventory are available.

21. How does/do the warehouse(s)/store(s) define the optimum level of inventory to maintain? (choose one)
- ○ No method to define the optimum level of inventory
- ○ Manual inventory management based on frequency of replenishment, stockouts, etc.
- ○ Dynamic policy on how much inventory should be maintained at the warehouse(s)/store(s) with defined min/max levels
- ○ Inventory segmentation used (reviewed quarterly)
- ○ Dynamic segmentation determined electronically by WMS or inventory management system
- ○ Not applicable
- ○ Don't know

22. How is the current physical count of inventory in the warehouse(s)/store(s) determined? (choose one)
- ○ No method to determine inventory physical count
- ○ Random audits to determine inventory physical count
- ○ Inventory policy used to determine inventory physical count
- ○ Regular (at least quarterly) inventory physical count
- ○ Frequency of inventory physical count dynamically determined by WMS
- ○ Not applicable
- ○ Don't know

23. Which of the following currently are constraints that prevent improvement of inventory management at warehouse(s)/store(s)? (choose all that apply)
- ☐ Human resources
- ☐ Improvement-process knowledge
- ☐ Enabling technologies
- ☐ Leadership/guidance
- ☐ National guidelines
- ☐ Funding
- ☐ Infrastructure
- ☐ Government support
- ☐ No public/private collaboration
- ☐ Other (please specify): ____________________________
- ☐ No constraints
- ☐ Not applicable
- ☐ Don't know

Comments/notes for this category:

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VI. Warehouse/Store Order Management

Supply-chain warehouses/stores can determine that the location needs to order more inventory, that the order is based on inventory policies, and then execute the order. As maturity increases, orders are created within a broader supply-chain digital platform as needed.

Objective: Coordinate order management at the warehouse(s)/store(s) with real-time demand from SDP/HFs and other warehouses/stores.

24. How are facility orders processed at the warehouse(s)/store(s)? (choose one)
   - O Difficult to process facility orders
   - O Ability to get facility orders to warehouse(s)/store(s)
   - O Established frequency to review and process orders
   - O Visual replenishment system (e.g., two-bin system) signals the need to process orders
   - O Orders are created and processed immediately upon request for product from SDP(s)/HF(s) or other warehouse(s)/store(s)
   - O Not applicable
   - O Don't know

25. What is the typical order ship-date request from the warehouse(s)/store(s) to SDP(s)/HF(s)? (choose one)
   - O No order ship-date requests provided
   - O Orders have extensive ship-date requests (more than two weeks of order)
   - O Orders have moderate ship-date requests (one to two weeks of order)
   - O Orders have short ship-date requests (within one week of order)
   - O Order management is connected to the supply-chain digital platform, enabling ship-date requests of one day of order or SDP(s)/HF(s) preferred date
   - O Not applicable
   - O Don't know

26. How are open orders in the warehouse(s)/store(s) identified and resolved? (choose one)
   - O No process to identify and resolve open orders
   - O Communication from SDP(s)/HF(s) triggers investigation into open order
   - O Open orders occasionally reviewed and resolved if problematic
   - O Open orders are reviewed weekly and actively resolved
   - O Open orders are actively managed and resolved via WMS and visible via supply-chain digital platform
   - O Not applicable
   - O Don't know

27. What is the complete-and-on-time delivery rate of warehouses/stores to SDPs/HFs? (choose one)

- ○ Delivery rate is not tracked
- ○ Less than 80%
- ○ 80% to 90%
- ○ 90% to 95%
- ○ Greater than 95%
- ○ Not applicable
- ○ Don't know

28. Which of the following currently are constraints that prevent improvement of order management at warehouse(s)/store(s)? (choose all that apply)

- ☐ Human resources
- ☐ Improvement-process knowledge
- ☐ Enabling technologies
- ☐ Leadership/guidance
- ☐ National guidelines
- ☐ Funding
- ☐ Infrastructure
- ☐ Government support
- ☐ No public/private collaboration
- ☐ Other (please specify): ____
- ☐ No constraints
- ☐ Not applicable
- ☐ Don't know

Comments/notes for this category:

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VII. Warehouse/Store Operations

Each warehouse/store can promptly receive, prepare, and ship inventory as required. As maturity increases, orders are picked accurately and moved efficiently to transportation provider(s).

Objective: Standardize warehouse/store stocking, picking, handling, and staging processes and eliminate wasteful steps to ensure product quality and increase process speed.

29. How are orders prepared for shipment? (choose one)

- ○ No process to determine when orders are shipped from warehouse(s)/store(s)
- ○ Ability to prepare inventory for shipment in less than one week from order receipt
- ○ Service level agreements (SLAs) for receiving and shipping within a specified time period are met
- ○ Orders are picked and staged ahead of transport arrival
- ○ Orders are picked and staged with pick path/routing determined by WMS
- ○ Not applicable
- ○ Don't know

30. What is the inventory accuracy of the warehouse(s)/store(s)? (choose one)

- ○ Inventory accuracy not regularly tracked
- ○ Less than 80%
- ○ 80%-90%
- ○ 90%-97%
- ○ Greater than 97%
- ○ Not applicable
- ○ Don't know

31. What method of quality control is used in warehouse(s)/store(s) to ensure product integrity? (choose one)

- ○ No quality control method
- ○ Quality defects randomly identified
- ○ A quality inspection process is performed during receipt (i.e. quantity, damage, sample testing)
- ○ A quality inspection process is performed during receipt and stocking
- ○ A quality inspection process is performed during all phases of operation (e.g., receipt, stocking, picking, staging)
- ○ Not applicable
- ○ Don't know

32. Which of the following currently are constraints that prevent improvement of operations at warehouse(s)/store(s)? (choose all that apply)

- ☐ Human resources
- ☐ Improvement-process knowledge
- ☐ Enabling technologies
- ☐ Leadership/guidance
- ☐ National guidelines
- ☐ Funding
- ☐ Infrastructure
- ☐ Government support
- ☐ No public/private collaboration
- ☐ Other (please specify): ______________________________
- ☐ No constraints
- ☐ Not applicable
- ☐ Don't know

Comments/notes for this category:

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Supply-Chain Components

VIII. Transportation

The supply chain can deliver product to service delivery points. Each location is documented, has a delivery schedule, knows what the delivery schedule is, and has a Proof of Delivery (POD) system in place. As maturity increases, route planning is conducted, appointments are defined, and product-delivery timing is measured and tracked.

Objective: Improve accuracy, timeliness, and efficiency of inventory transportation.

33. How is the movement of goods throughout the supply chain determined? (choose one)
    - O No standard method to schedule transportation
    - O Schedules set ad hoc
    - O Basic scheduled delivery mechanism
    - O Transport arrives on time for warehouse/store appointments with defined service level agreements (SLAs) that are measured and managed
    - O Transport arrives on time for warehouse/store appointments, SLAs are measured and managed, and real-time delivery tracking is visible via supply-chain digital platform.
    - O Not applicable
    - O Don't know

34. How are product deliveries communicated to facilities? (choose one)
    - O No communication with facilities regarding deliveries
    - O Facilities are informed of scheduled deliveries if they inquire about them
    - O Facilities are informed of scheduled deliveries by upstream parties
    - O Facilities can access delivery schedules; transport delivers on time to facility with defined service level agreements (SLAs) that are measured and managed
    - O Transport delivers on time to facility, defined SLAs are measured and managed, and real-time delivery tracking is visible via supply-chain platform
    - O Not applicable
    - O Don't know

35. How is the receipt of product at facilities verified? (choose one)
    - O No process to verify receipt of product at facilities
    - O Random proof of delivery (POD) by transporters
    - O Completed POD is returned to warehouse(s)/store(s)
    - O Electronic POD sent to warehouse(s)/store(s)
    - O Embedded devices (e.g., RFID tags) provide POD to warehouse management system
    - O Not applicable
    - O Don't know

36. Which of the following currently are constraints that prevent improvement of transportation of product throughout the supply chain? (choose all that apply)

- ☐ Human resources
- ☐ Improvement-process knowledge
- ☐ Enabling technologies
- ☐ Leadership/guidance
- ☐ National guidelines
- ☐ Funding
- ☐ Infrastructure
- ☐ Government support
- ☐ No public/private collaboration
- ☐ Other (please specify): ____
- ☐ No constraints
- ☐ Not applicable
- ☐ Don't know

Comments/notes for this category:

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IX. Expiry Management

Both warehouses/stores and service delivery points have policies to handle expired product. As maturity increases, quarantine areas are maintained and a "first- expired, first-out" (FEFO) policy is systematic and maintained.

Objective: Identify product in SDP/HFs and warehouse(s)/store(s) near expiration, minimize expired product, and prevent unsafe release of expired product.

37. What policies, guidance, and/or SOPs are in place at the SDP/HF and warehouse/store levels to identify and manage expired product? (choose one)

- ○ No policies or processes
- ○ Staff attempt to identify expired product on a regular basis
- ○ Policy, guidance, and/or SOPs for expiration management at facility is in place
- ○ FEFO picking policy for expiration is followed and audited
- ○ Standardized FEFO picking process is followed and audited and problems-solving occurs regularly to minimize potential for expired product
- ○ Not applicable
- ○ Don't know

38. What practices are in place at SDP/HF and warehouse/store levels to dispose of expired product? (choose one)

- ○ No practices to dispose of expired product
- ○ Staff are able to identify expired product
- ○ Staff actively track and document expired product
- ○ Staff actively track and document expired product and pull it from storage
- ○ Staff actively track and document expired product, pull it from storage, and dispose of it at designated sites according to policy/guidance/SOPs
- ○ Not applicable
- ○ Don't know

39. Which of the following currently are constraints that prevent improvement of expiry management? (choose all that apply)

- ☐ Human resources
- ☐ Improvement-process knowledge
- ☐ Enabling technologies
- ☐ Leadership/guidance
- ☐ National guidelines
- ☐ Funding
- ☐ Infrastructure
- ☐ Government support
- ☐ No public/private collaboration
- ☐ Other (please specify): ______________________________
- ☐ No constraints
- ☐ Not applicable
- ☐ Don't know

Comments/notes for this category:

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X. Procurement

The procurement process for product can be executed in a reasonable time frame. Within this maturity model, procurement is defined as the issuance of a purchase order to a previously established supplier, the approval of said purchase order by the vendor(s), shipment of goods, and receipt of goods. As maturity increases, the speed of the procurement process increases, levels are based on demand, and prices are competitive with national standards.

Objective: Rapidly procure the optimal amount of appropriately priced inventory to satisfy real-time demand.

40. How long does it take to procure product (purchase order under an existing contract)? (choose one)
- Procurement takes more than one month
- Procurement can be executed in less than one month
- Procurement can be executed in less than 2 weeks
- Procurement can be executed in less than 1 week
- Procurement can be executed in less than 1 week, with a process in place to compare supply-chain prices to national average at time of purchase
- Not applicable
- Don't know

41. How is the procurement quantity determined? (choose one)
- No standard process to determine procurement quantity
- Procurement quantity is based on count of existing supply and/or stockouts
- Procurement quantity is based on beneficiary consumption
- Procurement quantity is based on supply plan
- Procurement quantity is based on current system inventory levels and real-time demand forecasts
- Not applicable
- Don't know

42. What is the typical frequency for the procurement of product?
- Semiannually or less frequently
- Quarterly
- Monthly
- Weekly
- As needed
- Not applicable
- Don't know

43. Which of the following currently are constraints that prevent improvement of procurement processes? (choose all that apply)

- ☐ Human resources
- ☐ Improvement-process knowledge
- ☐ Enabling technologies
- ☐ Leadership/guidance
- ☐ National guidelines
- ☐ Funding
- ☐ Infrastructure
- ☐ Government support
- ☐ No public/private collaboration
- ☐ Other (please specify): ______________________________
- ☐ No constraints
- ☐ Not applicable
- ☐ Don't know

Comments/notes for this category:

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XI. Infrastructure and Assets

The buildings in the supply chain are appropriate for storing and managing products in sound condition. As maturity increases, internet access is prevalent at all locations and facility risks are identified and managed.

Objective: Establish buildings for product and personnel that are safe, secure, and technology-enabled.

44. How are products maintained in secure and sound condition at facilities? (choose one)

- ○ No standard process to keep products in secure and sound condition
- ○ Facilities have policies/guidance/SOPs to keep product dry
- ○ Conditions at all sites keep product dry
- ○ Conditions at all sites keep product dry, secure, and accessible only by authorized personnel
- ○ All sites keep product dry, secure, accessible only by authorized personnel, and in optimal environmental conditions specific to product type
- ○ Not applicable
- ○ Don't know

45. To what extent is internet access available at facilities? (choose one)

- ○ Few facilities have internet available
- ○ Internet is available at 50-80% of facilities
- ○ Internet is available at 80% of facilities
- ○ Internet is available at 100% of facilities
- ○ Internet available at a 100% of facilities and among those transporting product
- ○ Not applicable
- ○ Don't know

46. Which of the following currently are constraints that prevent improvement of supply-chain infrastructure and assets? (choose all that apply)

- ☐ Human resources
- ☐ Improvement-process knowledge
- ☐ Enabling technologies
- ☐ Leadership/guidance
- ☐ National guidelines
- ☐ Funding
- ☐ Infrastructure
- ☐ Government support
- ☐ No public/private collaboration
- ☐ Other (please specify): ______________________________
- ☐ No constraints
- ☐ Not applicable
- ☐ Don't know

Comments/notes for this category:

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XII. Performance Management

Each process in the supply chain has a defined set of performance indicators that are managed, and effort is made to improve them over time. Decision-making processes are driven by supply-chain data that populates scorecards. As maturity increases, data analytics are used in determining and improving supply-chain and staff performance.

Objective: Establish a system to align and continuously improve performance at all sites consistent with overall supply-chain goals.

47. How are problems and opportunities for improvement identified? (choose one)

- ○ No process to identify problems and opportunities
- ○ Problems identified as they occur
- ○ Measurement of basic key performance indicators (KPIs)
- ○ Decision-making processes are built upon reliable data inputs
- ○ Analytics drive gap analysis
- ○ Not applicable
- ○ Don't know

48. Describe the skill level of staff in identifying and solving problems? (choose one)

- ○ Staff have no problem-solving skills
- ○ Some staff have awareness of problem-solving skills (e.g., root-cause analysis)
- ○ Staff trained in basic problem-solving skills and lean tools (e.g., process-mapping, standardized work, 5 Whys)
- ○ Regular scorecard/dashboard reviews are conducted
- ○ Regular scorecard/dashboard reviews are conducted, with gap analysis driving problem-solving initiatives
- ○ Not applicable
- ○ Don't know

49. To what extent are teams empowered to solve problems independently? (choose one)

- ○ Teams are not empowered to solve problems independently
- ○ Teams are encouraged to suggest solutions to problems
- ○ Teams are able to take action on some KPIs (less than 50%) prior to scheduled scorecard/dashboard reviews
- ○ Teams are able to take action on most KPIs (50% to 80%) prior to scheduled scorecard/dashboard reviews
- ○ Teams are able to take action on all KPIs prior to scheduled scorecard/dashboard reviews
- ○ Not applicable
- ○ Don't know

50. Which of the following currently are constraints that prevent improvement of performance management? (choose all that apply)

- ☐ Human resources
- ☐ Improvement-process knowledge
- ☐ Enabling technologies
- ☐ Leadership/guidance
- ☐ National guidelines
- ☐ Funding
- ☐ Infrastructure
- ☐ Government support
- ☐ No public/private collaboration
- ☐ Other (please specify): ______________________________
- ☐ No constraints
- ☐ Not applicable
- ☐ Don't know

Comments/notes for this category:

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XIII. Analysis and Evaluation

The supply chain uses data to understand properly functioning processes and to identify deviations from the norm. Data from orders, shipments, receipts, and other supply-chain events are tracked to monitor process flow. As maturity increases, regular team reviews of supply-chain data and analytics identify areas for improvement.

Objective: Establish capabilities whereby data alerts sites and the overall supply chain to problems and opportunities for improvement.

51. How does data analysis and evaluation occur? (choose one)
   - ○ No data analysis and evaluation
   - ○ Data analyzed when a problem occurs
   - ○ Data analyzed for process deviation (e.g., missing orders, delays) to prevent problems
   - ○ Dedicated team for ongoing analysis and evaluation
   - ○ End-to-end supply-chain data analyzed to find areas for improvement
   - ○ Not applicable
   - ○ Don't know

52. How frequently are analysis findings reviewed? (choose one)
   - ○ No review of analysis findings
   - ○ Reviews occur at random
   - ○ Reviews of analysis findings occur at a regular frequency (quarterly or less often)
   - ○ Reviews of analysis findings occur at a regular frequency (at least monthly)
   - ○ Supply chain visibility and analytics network (VAN) provides data to make operational and strategic decisions, data is regularly reviewed, and actions taken to improve performance on an ongoing basis
   - ○ Not applicable
   - ○ Don't know

53. Which of the following currently are constraints that prevent improvement of analysis and evaluation processes? (choose all that apply)
   - ☐ Human resources
   - ☐ Improvement-process knowledge
   - ☐ Enabling technologies
   - ☐ Leadership/guidance
   - ☐ National guidelines
   - ☐ Funding
   - ☐ Infrastructure
   - ☐ Government support
   - ☐ No public/private collaboration
   - ☐ Other (please specify): ______________________________
   - ☐ No constraints
   - ☐ Not applicable
   - ☐ Don't know

Comments/notes for this category:

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XIV. Demand Planning/Management

The supply chain quantifies consumption and creates a forecast for future commodity requirements based on multiple factors (historical usage, known fluctuations, etc.). As maturity increases, the demand assumptions and plan are held in the broader supply-chain digital platform to influence decision-making.

Objective: Improve the accuracy of demand forecasting and eventually automate forecasting capabilities.

54. How is the demand plan created? (choose one)
- ○ There is no demand plan
- ○ Demand plan is being developed
- ○ Demand plan has been created (based on previous-year plan)
- ○ Demand plan has been created (based on actual consumption)
- ○ Demand plan has been created (based on actual consumption, external variables, etc.) and integrated into supply-chain digital platform
- ○ Not applicable
- ○ Don't know

55. How frequently is the demand plan checked for accuracy? (choose one)
- ○ Demand plan is not checked for accuracy
- ○ Demand plan can be tracked for accuracy (biannual — twice a year)
- ○ Demand plan can be tracked for accuracy (monthly or quarterly)
- ○ Demand plan can be tracked for accuracy (at least weekly)
- ○ Automated and dynamic demand plan tracking
- ○ Not applicable
- ○ Don't know

56. Which of the following currently are constraints that prevent improvement of demand planning/management? (choose all that apply)

- ☐ Human resources
- ☐ Improvement-process knowledge
- ☐ Enabling technologies
- ☐ Leadership/guidance
- ☐ National guidelines
- ☐ Funding
- ☐ Infrastructure
- ☐ Government support
- ☐ No public/private collaboration
- ☐ Other (please specify): ____
- ☐ No constraints
- ☐ Not applicable
- ☐ Don't know

Comments/notes for this category:

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XV. Supply Planning/Management

A strategy is in place for how the supply chain will maintain appropriate levels of each commodity. As maturity increases, the supply plan is based on demand and inventory, and is tracked in the broader supply-chain digital platform.

Objective: Plan and tightly coordinate supply-chain actions and inventories with the demand plan.

57. How is the supply plan created? (choose one)

- ○ There is no supply plan
- ○ Supply plan is being developed
- ○ Supply plan has been created (from demand plan)
- ○ Supply plan has been created (based on inventory policies)
- ○ Supply plan has been created (based on inventory policies, sourcing variables, etc.) and is included in supply-chain digital platform
- ○ Not applicable
- ○ Don't know

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58. Which of the following currently are constraints that prevent improvement of supply planning/management? (choose all that apply)

- ☐ Human resources
- ☐ Improvement-process knowledge
- ☐ Enabling technologies
- ☐ Leadership/guidance
- ☐ National guidelines
- ☐ Funding
- ☐ Infrastructure
- ☐ Government support
- ☐ No public/private collaboration
- ☐ Other (please specify): ____
- ☐ No constraints
- ☐ Not applicable
- ☐ Don't know

Comments/notes for this category:

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XVI. Fund Management

The sources of funds available to the supply chain are known, and commitments are documented and tracked. As maturity increases, funding needs are identified and managed actively in a broader supply-chain digital platform.

Objective: Improve accuracy and timeliness of fund-tracking in order to proactively pursue new funds to address emerging needs.

59. How are funding sources and commitments tracked and monitored? (choose one)

- ○ Overall fund amount/budget is not known and funds are not regularly released
- ○ Overall fund amount/budget is known and funds are released
- ○ Funding commitments are tracked and documented
- ○ Gaps in funding are identified based on analysis and actively managed
- ○ Budget and funding schedule are connected to the supply-chain digital platform
- ○ Not applicable
- ○ Don't know

60. Which of the following currently are constraints that prevent improvement of fund management? (choose all that apply)

- ☐ Human resources
- ☐ Improvement-process knowledge
- ☐ Enabling technologies
- ☐ Leadership/guidance
- ☐ National guidelines
- ☐ Funding
- ☐ Infrastructure
- ☐ Government support
- ☐ No public/private collaboration
- ☐ Other (please specify): ____
- ☐ No constraints
- ☐ Not applicable
- ☐ Don't know

Comments/notes for this category:

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XVII. Financial Management and Costing

Supply-chain costs incurred from procurement to receipt by the beneficiary are documented. As maturity increases, the supply chain establishes budgets based on known costs for each function at each facility, actively manages deviations, and has full visibility to the financials at each level.

Objective: Improve accuracy and timeliness of financial tracking across the supply chain to ensure optimal use of funds and establish appropriate budgets for the sites/overall supply chain.

61. How are supply-chain costs tracked? (choose one)

- ○ Little or no tracking of supply chain costs
- ○ Cost baseline completed
- ○ Ability to track supply-chain costs monthly
- ○ Financial deviations from target are actively managed
- ○ Full visibility to financials connected to the supply-chain digital platform
- ○ Not applicable
- ○ Don't know

62. Which of the following currently are constraints that prevent improvement of financial management and costing? (choose all that apply)

- ☐ Human resources
- ☐ Improvement-process knowledge
- ☐ Enabling technologies
- ☐ Leadership/guidance
- ☐ National guidelines
- ☐ Funding
- ☐ Infrastructure
- ☐ Government support
- ☐ No public/private collaboration
- ☐ Other (please specify): ______________________________
- ☐ No constraints
- ☐ Not applicable
- ☐ Don't know

Comments/notes for this category:

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XVIII. Governance

Appropriate structure is established to define roles and responsibilities for teams, individuals, and change agents within the supply chain. Teams have established goals and performance-management structures. As maturity increases, all processes are documented.

Objective: Roles for individuals, teams, and sites are clearly documented and understood, creating opportunities for collaboration, empowerment, and knowledge development.

63. To what extent are team roles and responsibilities within the supply chain understood? (choose one)

- ○ Team roles and responsibilities are not entirely clear
- ○ Team roles and responsibilities are clearly documented (RACI matrix — Responsible, Accountable, Consulted, and Informed — or similar completed)
- ○ Team goals are defined, tracked, and actively managed on a regular frequency (rhythm of business)
- ○ Processes between functional teams are understood and working
- ○ End-to-end team processes and performances are documented
- ○ Not applicable
- ○ Don't know

64. How would you describe leadership roles within the supply chain? (choose one)

- ○ Leadership roles are not fully staffed
- ○ Leadership roles are fully staffed
- ○ Leadership roles are fully staffed, with ongoing development of leadership capability
- ○ Leadership roles are fully staffed, with ongoing development of leadership capability; leaders facilitate stakeholder collaboration across the supply chain
- ○ Leadership roles are fully staffed, with ongoing development of leadership capability; leaders facilitate stakeholder collaboration across the supply chain and foster knowledge transfer from mature regions to regions that require improvement
- ○ Not applicable
- ○ Don't know

65. Which of the following currently are constraints that prevent improvement of governance processes? (choose all that apply)

- ☐ Human resources
- ☐ Improvement-process knowledge
- ☐ Enabling technologies
- ☐ Leadership/guidance
- ☐ National guidelines
- ☐ Funding
- ☐ Infrastructure
- ☐ Government support
- ☐ No public/private collaboration
- ☐ Other (please specify): ____
- ☐ No constraints
- ☐ Not applicable
- ☐ Don't know

Comments/notes for this category:

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XIX. Staff Training/Development

Staff have the skills to perform well in their positions. As maturity increases, staff have access to certifications, training and cross-training, and tools that will support their continued development.

Objective: Engage, educate/develop, and empower staff across the supply chain, improving their abilities to identify and solve supply-chain problems.

66. How knowledgeable are staff regarding supply-chain management processes, practices, and tools? (choose one)

- ○ Staff lack basic supply-chain knowledge
- ○ Staff have basic supply-chain knowledge (inventory management, logistics, etc.)
- ○ Staff are cross-trained and provided options for development
- ○ Staff are encouraged to pursue additional supply-chain related certifications
- ○ Staff collaborate closely with industry to keep the training/programs refreshed with latest trends/tools in supply-chain management.
- ○ Not applicable
- ○ Don't know

67. What expertise do staff have in supply-chain improvements? (choose one)

- ○ Most staff have little or no experience with supply-chain improvements
- ○ Some staff have experience with supply-chain improvements
- ○ Most staff have experience with supply-chain improvements and basic skills required to be effective in their roles
- ○ All staff have experience with supply-chain improvements and expertise in the skills required to be effective in their roles
- ○ All staff have experience with supply-chain improvements, expertise in the skills required to be effective in their roles, and most are able to train other staff
- ○ Not applicable
- ○ Don't know

68. Which of the following currently are constraints that prevent improvement of staff training and development? (choose all that apply)

- ☐ Human resources
- ☐ Improvement-process knowledge
- ☐ Enabling technologies
- ☐ Leadership/guidance
- ☐ National guidelines
- ☐ Funding
- ☐ Infrastructure
- ☐ Government support
- ☐ No public/private collaboration
- ☐ Other (please specify): ______________________________
- ☐ No constraints
- ☐ Not applicable
- ☐ Don't know

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Comments/notes for this category:

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XX Patient-Focused Performance

The supply chain and all parties within it measure last-mile product/medicine access, availability, and affordability, and collaboratively work to eliminate problems that impact product/medicine access, availability, and affordability.

Objective: Patients have efficient access to SDPs/HFs, and product/medicines are readily available and affordable.

69. Please rate patients' access to facilities and services. (choose one)
   - O Patient access to services is extremely challenging and/or patients experience excessive wait times at facilities
   - O Patients access to services is difficult and/or patients experience moderate to long wait times at facilities
   - O Patients access to services is reasonable and/or patients may experience some wait times at facilities
   - O Patients access to services is good and patients experience minimum wait times at facilities
   - O Patients access to services is excellent — including out-of-facility delivery options — and patients experience no wait times
   - O Not applicable
   - O Don't know

70. Please rate the availability of product/medicines at the facility(ies). (choose one)
   - O Less than 50% of products/medicines are available
   - O 50-75% of products/medicines are available
   - O 76-90% of products/medicines are available
   - O 91-99% of products/medicines are available
   - O 100% of products/medicines are available
   - O Not applicable
   - O Don't know

71. How do facility procurement prices for products/medicines impact patients? (choose one)
   - Most prices (>70%) are cost-prohibitive and well above facility budgets — most products/medicines cannot be acquired for patients
   - Many prices (50-70%) are cost-prohibitive and above facility budgets — many products/medicines cannot be acquired for patients
   - Some prices (30-50%) are cost-prohibitive and above facility budgets — some products/medicines cannot be acquired for patients
   - Most prices (>70%) are affordable and within facility budgets — most products/medicines can be acquired for patients
   - All prices are affordable and within facility budgets — all products/medicines can be acquired for patients
   - Not applicable
   - Don't know

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72. Which of the following currently are constraints that prevent improvement of access, availability, and affordability? (choose all that apply)

- ☐ Human resources
- ☐ Improvement-process knowledge
- ☐ Enabling technologies
- ☐ Leadership/guidance
- ☐ National guidelines
- ☐ Funding
- ☐ Infrastructure
- ☐ Government support
- ☐ No public/private collaboration
- ☐ Wait times at facilities
- ☐ Other (please specify): ______________________________
- ☐ No constraints
- ☐ Not applicable
- ☐ Don't know

Comments/notes for this category:

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When you submit your assessment, you will be given an opportunity to review your answers and save a copy of your responses:

1. Click on "Submit your assessment" below.
2. You will then be presented with your entire questionnaire as a single, scrollable page. At the top of the page is a "Download PDF" option.
3. Review your answers.

1. If you ARE satisfied with your answers:
    1. Scroll to the bottom of the page and click on "Submit your assessment." You will automatically access the data visualization website and your Assessment Output.
2. If you ARE NOT satisfied with your answers:
    1. Click on "Previous category" and revise your answers as necessary. When you are finished, proceed to the end of the assessment questionnaire and repeat the submission process (Steps 1, 2, and 3.1).

APPENDIX V: IN-DEPTH INTERVIEW PROTOCOL

Table 1: Interview protocol for in-depth interviews

Questions for in-depth interviews
1. How do inter-departmental teams (pharmacy, accounts, procurement etc) work together in the organization to make medicines available?
2. What should be done to improve how teams work together?
3. Can you describe how your inter-departmental teams work with your patients and suppliers to provide medicines?
4. Can you describe how the teams work with suppliers to make medicines available?
5. In your own perspective, how can inter-departmental teams improve working relationship with patients?
6. In your own opinion, how can inter-departmental teams improve working relationship with suppliers?
7. In your own opinion, how can inter-departmental teams improve working relationship with critical stakeholders (donor/partner, government/regulators/ CSOs etc)
8. Can you describe how you share information about medicines and other health supplies with patients, suppliers, and other critical stakeholders (donor/partner, government/regulators/ CSOs)?
9. Describe how you share logistic information (stock level, available medicines, expiries, expected medicines etc)?
10. In your opinion, what should be done to improve information-sharing with patients, suppliers, and other critical stakeholders (donor/partner, government/regulators/ CSOs)?
11. In your opinion, what do you think about the use of digital technology for making medicines available?

12. What type of digital technology do you have experience with in making medicine available?

13. In your opinion, explain how would you measure the performance of medicine availability in your organization?

14. In your opinion, describe how the inter-departmental teams can improve performance by working with patients, suppliers, and other critical stakeholders (donor/partner, government/regulators/ CSOs)?

APPENDIX VI: SURVEY PILOT STUDY INCLUSION AND EXCLUSION CRITERIA

Table 1: Survey Pilot Study Inclusion and Exclusion Criteria

Inclusion Criteria	**Exclusion Criteria**
Works in the field of Supply chain management	Less than 3-years' experience in DRF program
Works in healthcare supply chain organisation	Refusal to give consent
Have complete understanding of supply chain operations	
Works in academia teaching supply chain management	
Understands Drug Revolving Funds operations	

APPENDIX VII: LIST AND DEFINITION OF INTEGRATED SUPPLY CHAIN MODEL VARIABLES

Table 1: List and definition of integrated supply chain model variables

No	Endogenous variables	Definition of Endogenous Variables	Exogenous variables	Definition of Exogenous Variables
1	Accounts payable	Money to be paid to suppliers for procurement of drugs.	Allocated funding per week	Amount of cash given to hospital by government
2	Accounts receivable	Money to be paid to hospital for medicines sold on credit to internal customers like other Departments within the hospital.	Hospital time period for adjusting medicine in transit	Time to correct hospital medicines to be delivered
3	Adequacy of product mix	Enough variety of medicines to meet customer needs	Hospital time period for averaging orders	Time to average customer orders
4	Bad debt	Outstanding receivables that are not recoverable and written off the books	Hospital time period for medicine inventory holdings	Time to store hospital medicines
5	Buying on credit	Medicines sold to customers on credit	Markup	The value that hospitals add to the cost price
6	Cash at Bank	Cash deposited in hospital account	"1 week"	Per week

7	Cash collected at hospital	Cash collected from patients for sales of medicines	Percent shrinkage and expiries per week	Value of medicines loss from expiries, wastages, and pilferages
8	Credit score	Predicts the credit behaviour of hospitals if they will pay for medicines delivered on-time	Normal time period for reconciling inventory	Normal time it takes to reconcile inventory
9	Depositing cash	Monies deposited in hospital account from all sources of fund	Purchase price	Medicine price paid by hospital
10	Desired delivery	Medicines that the hospital wishes to receive	Rate of payment	Frequency of paying receivables
11	Effect of adequacy of product mix on trust	Result of having enough medicine mix on trust	Supply delay	Period of late delivery
12	Effect of adequacy on fill rate	Result of having enough medicine mix on fill rate	Time to pay suppliers	Period of paying suppliers for deliveries
13	Effect of credit score on order fulfilment	Result of hospital ability to pay for delivered medicines on getting their orders fulfilled	Sweffect of selling activity on reconciling time	Outcome switch
14	Effect of selling activity on reconciling time	Outcome of medicine sales on time to reconcile medicines	Weekly percent bad debt	Period of outstanding receivables that are not recoverable and written off the books
15	Fill rate	The percent of available medicines in a prescription	Weeks of cash at bank	Period of cash in the hospital account

16	Getting paid	Frequency of receiving cash for credit sales	Distributor delivery delay	Period of distributor late delivery
17	Government funding	Cash given to hospital for medicine provision	Manufacturing cycle time=	Period it takes to transform raw materials into finished products
18	Hospital average order rate	Time for hospital to average orders in preparation for procurement	Distributor time period for adjusting medicine in transit	Time to correct distributor medicines to be delivered
19	Hospital customer orders	Number of medicine orders received from customers per week	Distributor time period for averaging orders	Time to average hospital orders
20	Hospital desired medicine in transit	Number of medicines that the hospital wishes to receive from distributor	Distributor time period for medicine inventory holdings	Time to store distributor medicines
21	Hospital desired medicine inventory	Number of medicines that the hospital wishes to stock	Distributor time period for reconciling medicine inventory	Time to reconcile distributor medicine inventory
22	Hospital medicine in transit correction	Adjustment to number of medicines before delivery	Manufacturer time period for adjusting medicine in transit	Time to correct manufacturer medicines to be delivered
23	Hospital medicine inventory	Number of medicines in hospital stock	Manufacturer time period for averaging orders	Time to average distributor orders
24	Hospital medicine inventory correction	Medicines adjustment for hospital stock	Manufacturer time period for medicine inventory holdings	Time to store manufacturer medicines

25	Hospital medicine on order	Number of medicines orders placed by the hospital	Manufacturer time period for reconciling medicine inventory	Time to reconcile manufacturer medicine inventory
26	Hospital selling	Number of medicines sold by hospitals to customer	Percent internal marketing	Value of medicines sold on credit to internal customers
27	Hospital time period for reconciling medicine inventory	Time to reconcile hospital medicine inventory	—	—
28	"Hospital-stakeholder trust"	Value of medicines mix on stakeholder trust in the supply chain.	—	—
29	Order fulfilment	Number of medicines delivered to hospital	—	—
30	Order procurement	Number of medicines procured by hospital	—	—
31	Normal customer orders	Number of orders received from hospital customer	—	—
32	Order procurement rate	Frequency of buying medicines by hospitals	—	—
33	Paying cash	Amount of money available in bank to pay suppliers	—	—

34	Paying suppliers	Amount of money paid to suppliers for medicines delivered to hospital	—	—
35	Percent cash sales	Value of medicines sold on cash and carry basis	—	—
36	Selling activity ratio	Relative value of sales from normal customer order	—	—
37	Selling on credit	Cash value of medicines sold on credit from hospital	—	—
38	Shrinking and expiring inventory	Number of medicines loss from expiries, wastages, and pilferages	—	—
39	Weeks of payables	Time of debt owed to medicine suppliers	—	—
40	Desired production	Number of medicines that manufacturers wish to produce	—	—
41	Desired production rate	Frequency of producing medicines as required by the manufacturer	—	—
42	Desired work in process	Number of raw materials desired by manufacturer	—	—

43	Distributor average order rate	Time for distributor to average orders in preparation for procurement	—	—
44	Distributor customer orders	Number of medicine orders received from hospitals per week	—	—
45	Distributor desired medicine inventory	Number of medicines that the distributor wishes to stock	—	—
46	Distributor desired order rate	Number of medicines that the distributor wishes to stock	—	—
47	Distributor desired shipment	Medicines that the distributor wishes to receive	—	—
48	Distributor medicine in transit	Number of medicines that the distributor wishes to receive from manufacturer	—	—
49	Distributor medicine in transit correction	Adjustment to number of medicines before delivery from manufacturer	—	—
50	Distributor medicine inventory	Number of medicines in distributor stock	—	—

51	Distributor medicine inventory correction	Medicines adjustment for distributor stock	—	—
52	Distributor selling	Number of medicines sold by distributor to hospital	—	—
53	Manufacturer average order rate	Time for manufacturer to average orders in preparation for production	—	—
54	Manufacturer customer orders	Number of medicine orders received from distributor per week	—	—
55	Manufacturer desired medicine inventory	Number of medicines that the manufacturer wishes to stock	—	—
56	Manufacturer medicine inventory	Number of medicines in manufacturer stock	—	—
57	Manufacturer medicine inventory correction	Medicines adjustment for manufacturer stock	—	—
58	Manufacturer selling	Number of medicines sold by manufacturer to distributor	—	—
59	Manufacturer work in process	Number of manufacturer raw materials stock	—	—

60	Order rate	Number of medicines procured by distributor	—	—
61	Production rate	Actual frequency of producing medicines by the manufacturer	—	—
62	Shipment	Number of medicines delivered to distributor	—	—
63	Work in process correction	Unfinished raw material adjustment for manufacturer stock	—	—
64	Distributor desired medicine in transit	Number of medicines that the distributor wishes to receive from manufacturer	—	—
65	Sell price per unit	Medicine price paid by the customer	—	—

APPENDIX VIII: SIMULATION MODEL EQUATIONS SHOWING VARIABLES AND FORMULARS

Definition of variables and formulars for Medicine Inventory Model Simulation

No	**Endogenous Variables with units and formulars**	**Exogenous Variables with units**	**Variables not used in the model**
1	Accounts Payable= INTEG (buying on credit-paying suppliers, 960000) Units: naira	allocated funding per week=1000 Units: naira/Week [0,100000,100]	Medicines quality
2	Accounts Receivable= INTEG (selling on credit-bad debt-getting paid, 436594) Units: naira	hospital time period for adjusting medicine in transit=4 Units: Week [2,10,2]	Drug abuse
3	adequacy of product mix= Hospital Medicine Inventory/hospital desired medicine inventory Units: Dmnl	hospital time period for averaging orders= 4 Units: Week	Productivity

4	bad debt= Accounts Receivable*weekly percent bad debt Units: naira/Week	hospital time period for medicine inventory holdings= 8 Units: Week	Benchmarking
5	buying on credit= order fulfillment*purchase price Units: naira/Week	markup= 1.2 Units: Dmnl [0.8,2,0.1]	Corruption
6	Cash at Bank= INTEG (depositing cash-paying cash, 1e+06) Units: naira	"1 week"= 1 Units: Week	Substandard medicine exposure
7	cash collected at hospital= hospital selling*sell price per unit 0*percent cash sales Units: naira/Week	percent shrinkage and expiries per week= 0.04 Units: Dmnl/Week [0,1,0.01]	Reverse logistics

8	credit score= time to pay suppliers/weeks of payables Units: Dmnl	normal time period for reconciling inventory= 8 Units: Week [1,8,1]	Cost to serve
9	depositing cash= cash collected at hospital+getting paid+government funding Units: naira/Week	purchase price= 80 Units: naira/units	
10	desired delivery= MAX(0,hospital average order rate+hospital medicine inventory correction) Units: units/Week	rate of payment= 50 Units: Week [4,104,2]	
11	effect of adequacy of product mix on trust= WITH LOOKUP (adequacy of product mix, ([(0,0)-(2,1)],(0,0.1),(0.2,0.3),(0.4,0.5),(0.6,0.8),(1,1),(2,1))) Units: Dmnl	supply delay= 1 Units: Week [0.5,4]	

12	effect of adequacy on fill rate= WITH LOOKUP (adequacy of product mix, ([(0,0)-(2,2)],(0,0),(0.3,0.4),(0.5,0.6),(1,1),(2,1.2))) Units: Dmnl	time to pay suppliers= 4 Units: Week [0.5,20,1]	
13	effect of credit score on order fulfillment = WITH LOOKUP (credit score, ([(0,0)- (1.5,2)],(0,0),(0.2,0.1),(0.2,0.1),(0.4,0.3),(0.6,0.8),(0.8,1),(1,1),(1.5,1.1))) Units: Dmnl	sweffect of selling activity on reconciling time= 0 Units: Dmnl	
14	effect of selling activity on reconciling time([(0,0)-(4,2)],(0,0.5),(1,1),(2,1.5),(4,2)) Units: Dmnl	weekly percent bad debt= 0.7/52 Units: Dmnl/Week	
15	fill rate= effect of adequacy on fill rate Units: Dmnl	weeks of cash at bank= 2 Units: Week [0.5,10,1]	

16	getting paid= Accounts Receivable/rate of payment Units: naira/Week	distributor delivery delay=1 Units: Week	
17	government funding= "hospital-stakeholder trust"*allocated funding per week Units: naira/Week	manufacturing cycle time= 1 Units: Week	
18	hospital average order rate= SMOOTH(hospital customer orders,hospital time period for averaging orders) Units: units/Week	distributor time period for adjusting medicine in transit= 4 Units: Week	
19	hospital customer orders= normal customer orders Units: units/Week	distributor time period for averaging orders= 4 Units: Week	

20	hospital desired medicine in transit= desired delivery*supply delay Units: units	distributor time period for medicine inventory holdings= 8 Units: Week	
21	hospital desired medicine inventory= hospital average order rate*hospital time period for medicine inventory holdings Units: units	distributor time period for reconciling medicine inventory= 4 Units: Week	
22	hospital medicine in transit correction= (hospital desired medicine in transit-Hospital Medicine On Order)/hospital time period for adjusting medicine in transit Units: units/Week	manufacturer time period for adjusting medicine in transit = 4 Units: Week	
23	Hospital Medicine Inventory= INTEG (order fulfillment-hospital selling-shrinking and expiring inventory, 24000) Units: units	manufacturer time period for averaging orders = 4 Units: Week	

24	hospital medicine inventory correction= (hospital desired medicine inventory-Hospital Medicine Inventory)/hospital time period for reconciling medicine inventory Units: units/Week	manufacturer time period for medicine inventory holdings = 8 Units: Week	
25	Hospital Medicine On Order= INTEG (order procurement-order fulfillment, 3000) Units: units	Manufacturer time period for reconciling medicine inventory= 4 Units: Week	
26	hospital selling= min(hospital customer orders,Hospital Medicine Inventory/"1 week")*fill rate Units: units/Week	percent internal marketing= 0.4 Units: Dmnl [0,1,0.1]	
27	hospital time period for reconciling medicine inventory= IF THEN ELSE(sweffect of selling activity on reconciling time>0,effect of selling activity on reconciling time		

	(selling activity ratio),1)*normal time period for reconciling inventory Units: Week		
28	"hospital-stakeholder trust"= effect of adequacy of product mix on trust Units: Dmnl		
29	order fulfillment= Hospital Medicine On Order/supply delay*effect of credit score on order fulfillment Units: units/Week		
30	order procurement= order procurement rate Units: units/Week		
31	normal customer orders= 3000+0*PULSE(5,5)*1500 Units: units/Week [3000,8000,1000]		
32	order procurement rate= desired delivery+hospital medicine in transit correction		

	Units: units/Week		
33	paying cash= paying suppliers Units: naira/Week		
34	paying suppliers= min(Accounts Payable/time to pay suppliers,Cash at Bank/weeks of cash at bank) Units: naira/Week		
35	percent cash sales= 1-percent internal marketing Units: Dmnl		
36	selling activity ratio= hospital selling/normal customer orders Units: Dmnl		
37	selling on credit=		

	hospital selling*sell price per unit 0*percent internal marketing Units: naira/Week		
38	shrinking and expiring inventory= Hospital Medicine Inventory*percent shrinkage and expiries per week Units: units/Week		
39	weeks of payables= Accounts Payable/paying suppliers Units: Week		
40	desired production= MAX(0,manufacturer average order rate+manufacturer medicine inventory correction) Units: units/Week		
41	desired production rate=		

	desired production+work in process correction Units: units/Week		
42	desired work in process= desired production*manufacturing cycle time Units: units		
43	distributor average order rate= SMOOTH(distributor customer orders,distributor time period for averaging orders) Units: units/Week		
44	distributor customer orders= order procurement rate Units: units/Week		
45	distributor desired medicine inventory= distributor average order rate*distributor time period for medicine inventory holdings		

	Units: units		
46	distributor desired order rate= distributor desired shipment+distributor medicine in transit correction Units: units/Week		
47	distributor desired shipment= distributor average order rate+distributor medicine inventory correction Units: units/Week		
48	Distributor Medicine In Transit= INTEG (order rate-shipment, 3000) Units: units		
49	distributor medicine in transit correction= (distributor desired medicine in transit-Distributor Medicine In Transit) /distributor time period for adjusting medicine in transit		

	Units: units/Week		
50	Distributor Medicine Inventory= INTEG (shipment-distributor selling, 24000) Units: units		
51	distributor medicine inventory correction= (distributor desired medicine inventory-Distributor Medicine Inventory)/distributor time period for reconciling medicine inventory Units: units/Week		
52	distributor selling= distributor customer orders Units: units/Week		
53	manufacturer average order rate = SMOOTH(manufacturer customer orders,manufacturer time period for averaging orders) Units: units/Week		

54	manufacturer customer orders= distributor desired order rate Units: units/Week		
55	manufacturer desired medicine inventory = manufacturer average order rate*manufacturer time period for medicine inventory holdings Units: units		
56	Manufacturer Medicine Inventory= INTEG (production-manufacturer selling, 24000) Units: units		
57	manufacturer medicine inventory correction = (manufacturer desired medicine inventory-Manufacturer Medicine Inventory) /manufacturer time period for reconciling medicine inventory Units: units/Week		

58	manufacturer selling = manufacturer customer orders Units: units/Week		
59	Manufacturer Work In Process= INTEG (production rate-production, 3000) Units: units		
60	order rate= manufacturer selling Units: units/Week production= DELAY FIXED(production rate,manufacturing cycle time,3000) Units: units/Week		
61	production rate= desired production rate Units: units/Week		

62	shipment= DELAY FIXED(order rate,distributor delivery delay,3000) Units: units/Week		
63	work in process correction= (desired work in process-Manufacturer Work In Process)/manufacturer time period for adjusting medicine in transit Units: units/Week		
64	distributor desired medicine in transit= distributor desired shipment*distributor delivery delay Units: units		
65	sell price per unit 0= purchase price*markup Units: naira/units [70,100,10]		

APPENDIX IX: INTERVIEW ANALYSIS FOR CASE A

Interview Quotation Analysis for Case A

IS03

ParticipantNumber-Quote number) "... variables in Phrase(s)" (word count in variables/total word count in causal statement)	Phrase(s) from participant quote denoting model variables	Interpreted model variables	Causal link between model variables (→=causal link, --||→=causal link with delay, +/-=positive or negative polarity)	Themes from participant quotes
IS03-01) "… teams to achieve strategic goals by knowing what everyone does. The accountant makes sure <u>fund</u> is available to <u>procure drugs</u>. The procurement sets all the means to <u>communicating</u> or getting suppliers to <u>bring the drugs</u> and make it available. And then the pharmacy who dispenses this drug … making it available for <u>patients</u>. So, having each of these department knowing what they are supposed to do in order to ensure the	- fund - procure drugs - communicating - bring the drugs - patients - overall goal	Cash at bank Order procurement Communication Order fulfilment Customer orders Fill rate	Customer orders→+Cash at bank→+Order procurement→+Communication→+Order fulfilment→+Fill rate	**Internal integration** When teams work together, procurement of medicines increases, and fill rate also increase.

overall goal of the organisation is met…”. (78/109)				
IS03-02) “… The pharmacy ensures that the products required or medicines that are required by the patient, or that has been agreed to be supplied to hospital is available as a list. Medicine that's supposed to be available for patient is known… the accountants ensures that funds are well managed. He ensures that there is money available to procure those medicines, and even if these medicines are to be sold he ensures that this money is collected back to make these medicines available … The right suppliers … supply these medicines so the pharmacist … ensures the quality of medicines, quality control and quality assurance of this medicine and … dispenses them to the patients…”. (113/232)	- available as a list - money - well managed - procure - collected - quality - dispenses	Average order Cash at bank Depositing cash Order procurement Cash collected at hospital Medicine quality Selling	Average order→+ Order procurement→+ Medicine quality→+ Selling→+Cash collected at hospital→+ Depositing cash→+Cash at bank	**Cash flow integration** Cash and medicines flow in the hospita8l

IS03-03) "… the organisation should really learn to move away from silo functions, … they need to be more vertical functions where these different units come together and see how their functions inter-relate so that performance will be measured in terms of the <u>collective activities</u> of these different units, and not just in single unit. So, this can be done through consistent meetings, having <u>sales and operations</u> meeting setting targets that involve all the unit of performers ... And then really living up to the values that the organisation sets and knowing what those values are and how it would help them <u>attain their goals</u> at the end of the day". (109/138)	- collective activities - sales and operations - attain their goals	Fill rate Process integration Customer satisfaction	Process integration→+ Fill rate→+Customer satisfaction	**Internal integration** Measuring performance as a team with shared goals of serving the customer.
IS03-04) "…we work with the pharmacy unit by getting information on <u>what they need</u>, how much <u>quantity they</u>	- what they need - quantity they have	Average order rate Inventory holdings	Customer orders→+ Average order rate	**Cash flow integration**

have what they have used out of what they have and make a decision on what to supply them. …We receive and ensure the quality of the items are maintained. … we get funds from the hospital which we use to pay for procurement upstream to suppliers…". (64/187)	- have used - supply them - quality - funds - procurement	Customer orders Order fulfilment Medicine quality Cash collected at hospital Order procurement rate	→+ Order procurement rate→+ Order fulfilment→+ Inventory holdings→+ Medicine quality→+ Cash collected at hospital	Procuring quality medicines increases patients increases cash flows.
IS03-05) "… we need to start seeing ourselves as an integral part of the downstream, seeing the patients themselves so we need to we need to be able to know what the patient is going through, need to be able to put ourselves in a position to see what the patient needs. … we need to be able to see and communicate downstream to the final end-users. …". (68/152)	- part of the downstream - patient is going through - patient needs	Process integration Customer satisfaction Fill rate	Process integration→+ Fill rate→+Customer satisfaction	**Customer integration** There is a need to know how satisfied customer are with their services.

IS03-06) "…suppliers…are a very integral part of the supply chain, because they provide the medicines, we need to be able to improve our service level to provide patient and improve the <u>health index</u> downstream. Now we work with the suppliers through the <u>contracts</u> we have with them through being able to be true to our words when we say we'll <u>pay</u> them <u>at a certain time</u>, we are able to pay them, and when we make an agreement, we don't <u>betray that agreement</u>, and we work … to build <u>partnerships</u> are not adversarial relationship. … And then, …donor is coming to provide that same product, which is probably going to be … at par with the contract signed with the supplier. So, somebody else is bringing that item, even though we have signed contracts of getting it from a	- health index - contracts - pay - betray that agreement - at a certain time - partnerships - communication and understanding - one thing and then the next	Fill rate Contract management Paying suppliers Hospital-supplier relationship (trust) Delay Partnerships Communication Delay	Contract management--//→+Partnerships→+ Communication→+Fill rate--//→+ Paying suppliers→+Hospital-supplier relationship (trust)	**Network integration** There appears to be tensions between working with medicine suppliers and donors. Although, the donor is trying to help by donating the same medicines being supplied by suppliers without considering the ongoing contracts with the organisation's suppliers. This leads to breach of

supplier, I think there need to be very good <u>communication and understanding</u>, to be able to work with both the donor and the supplier, not agree with the supplier on <u>one thing and then the next</u> thing go behind them and do something else so we need to build partnership with the suppliers and ensure we have mutual benefits and not just the sole benefit for ourselves and not considering what the circumstance of the supplier will be if we don't meet the terms of contract we have signed with them". (229/298)				contract as the organisation is not able to pay suppliers on time.
IS03-07) **"**… we work well with stakeholders … enlightening them about the organisation rules or regulations, making them see the value we are providing … to ensure <u>medicine availability</u> in the facility. We … get	- medicine availability - last mile delivery - wastage	Fill rate Order fulfilment Shrinking and expiring inventory	Order fulfilment→-Partnership→+Collaboration→-Shrinking and expiring inventory→- Fill rate	**Network integration** Staff are frustrated at the lack of shared values with partners

information from those facilities…. and … ensure we get the <u>last mile delivery</u> to them, and also ensure that there is no <u>wastage</u> in the supply chain. If donor does not understand or know our rules, our laws …. they … may begin to act in a way as competing to those goals providing medicine to facility that we are already providing and causing wastage in the facility. … I would expect the donor organisation having known or being enlightened about our laws and values should form a team and <u>partnership</u> with us to provide and meeting those goals, so we need to <u>work together</u> with the partners … and unite it for the good of the patients we are serving". (155/215)	- partnership - work together	Partnership Collaboration		and competition by sending drugs to the same hospitals leading to expiries. partnerships and collaboration to align the SCs is necessary.
IS03-08) "… for patients, <u>information</u> they get about medicines and other health supplies, It's not really a very	- information - publicise	Information sharing Visibility	Medicine inventory→+ Selling→+	**Customer integration**

strong thing we do in our organisation, however, we have made sure we have platforms such as the state websites to <u>publicise</u> our monthly price lists where the patient can see the information on the commodities they get, the <u>true price</u> of that commodity, such that they will not be cheated once <u>they get that item</u>, …, and they also have the right to get that product anywhere within the state at <u>that same price</u>. … However, knowing <u>the stock</u> of these item is what we haven't really been able to achieve yet …". (109/172)	- true price - they get that item - that same price - the stock	Transparency Selling Medicine equity Medicine inventory	Information sharing→+Visibility →+Transparency→+ Medicine equity	Price visibility empowers patients to get medicines at equitable prices. It also prevents exploitation of patients by information asymmetry and price gouging in hospitals.
IS03-09) **"**In terms of the suppliers, we have been able to <u>partner</u> with them to get them to see our stock level and knowing what we need them to supply. We have a system and a dashboard which we <u>have shared</u> with some of our	- partner - have shared - service level	Partnership Visibility Fill rate	Partnership→+ Information sharing→+Visibility →+Fill rate	**Supplier integration** Suppliers do not have visibility to the SC dashboard.

critical stakeholders like the government. This dashboard speaks to what we have been able to do in terms of our service level e.g. how many patients we have served, how much does it cost us to serve those patients, … as well as the types of products or programmes, whether free or DRF programmes. we have been able to populate this information in a system where critical stakeholders have access to view information. However, we still haven't been able to share that information with suppliers which I think is also a setback which we should look towards achieving going forward". (144/154)	- view information	Information sharing		
IS03-10) "… the use of digital medicine has really revolutionised the supply chain, in terms of making decisions, very fast, and ensuring medicine availability, availability through getting the right	- digital - medicine availability - procure medicines	Digital technology Fill rate Order procurement	Average orders→+Digital technology→+ Information sharing→+ Order	**Information integration** Use of digital technology

information to <u>procure medicines</u> needed, also cutting down <u>wastage</u> and also helping proper <u>planning</u> to reduce <u>lead time</u> so that with proper <u>information</u>, orders are placed, and medicines arrive before it runs out or get <u>stocked out</u>. …". (66/106)	- wastage - planning - lead time - information - stocked out	Shrinking and expiring inventory Average orders Supply delay Information sharing Stockout	procurement→- Supply delay→+ Shrinking and expiring inventory→+ Fill rate→-Stockout	platforms reduces supply delay and expiries.
IS03-11) **"**… we use an <u>online, cloud-based system</u> where medicines from the downstream are sent via SMS, through to the cloud-based system, so that we're able to get <u>information</u> about what was used in the downstream, point of sale information are sent, <u>stock available</u> on the shelves are sent regularly through this cloud-based system called the SMS dashboard … it transmits this message	- online, cloud-based system - information - stock available - analysis - aggregate stock	Digital technology Information sharing Medicine inventory Data-driven analysis Average order rate	Medicine inventory→+Digital technology→ →+Data-driven analysis→+Information sharing→+ Average order rate→+ Desired delivery→-Time period for inventory	**information integration** Use of advanced analytics platforms increase procurement and reduce expiries

via SMS … for analysis on a business intelligence … platform to make analysis such as the aggregate stock and the quantity to order, as well as suppliers information and months of stock available and then other very critical information like when commodities will expire and then what to do before expiring". (114/160)	- quantity to order - months of stock available - expire	Desired delivery Time period for inventory holdings Shrinking and expiring inventory	holdings→Shrinking and expiring inventory	
IS03-12) "we use the warehouse management system … to significantly help us manage stock in the warehouse, we're able to use this system to move stock from the warehouse, collect proof of deliveries, pick and pack items, and also segregate medicines for different programmes in the warehouse. So, it has been a very good tool for managing for warehouse management". (59/69)	- warehouse management system -manage stock - warehouse management	Digital technology Reconciling inventory Inventory management	Inventory management→+ Digital technology→- Reconciling inventory	**Internal integration** Digital technology helps in managing inventory efficiently.

IS03-13) "… we <u>measure how long it takes to serve a customer</u> so we've been able to set service level whereby we examine stock of all our customers in all the facilities every 20 days, such that within the 20 days we're able to look at the stock and measure, and give them products when they're close to being <u>stocked out</u>. twenty-five days products are given to the facilities based on their consumption. And then, <u>beyond the twenty days</u>, the dashboard begins to turn red to indicate that we haven't been able to meet that service level. we also measure the <u>order fill rate</u>. So, if an order is generated by our system, how much of this order are we able to fill, up to 90% or 70% So, our performance is measured by how much order we are able to fill. … they may be more in terms of <u>budget</u>	- measure how long it takes to serve a customer - order fill rate - stocked out - budget performance - beyond the twenty days	Waiting time Fill rate Stockout Financial performance Time delay	Stockout →+Waiting time→-Fill rate--//→+Financial performance	**Cash flow integration** Managing performance with key performance indicators helps reduce wait time s and increase fill rate.

performance, …we have set budget in a year to do certain activities, how much of those activities, have we been able to execute …”. (173/242)				
IS03-14) “…even though we are able to measure some internal performance. Presently I think they are more or less, internal, I think there is a need to bring in our customers, stakeholders perspective into this. So there is a need to get the view of patients towards our service level so I think we need to start measuring our service level, based on patient perspective and stakeholders perspective, we need to start having periodic reviews by our customers and our stakeholders to see how much we are performing, how well we need to improve our lapses, and then know our performance from both external and	- internal performance - customers, stakeholders perspective - patients towards our service level	Internal performance External performance Customer satisfaction	Internal performance→+External performance→+Customer satisfaction	**Network integration** It is important to view and measure performance from stakeholder and customer perspective

internal function within the organisation. … (109/128)				
IS03-15) "… our level of transparency, I think we also need to improve that, we need to … be more transparent towards our suppliers, and also towards the government being transparent, doesn't just mean showing off what you are doing, but rather, showing to know where the lapse is, and then to be …reviewed so that we could get the side of the suppliers to say …, why not do it this way or this will work better, why not try it differently. … I think it will also help measure our performance and improve our interaction with stakeholders, and suppliers. (99/154)	- transparency - the lapse - interaction with stakeholders, and suppliers	Transparency Fill rate Hospital-stakeholder relationship (trust)	Transparency→+Hospital-stakeholder relationship (trust)→+Fill rate	**Network integration** Requires trust between all partners and transparency.
IS03-16) "… civil society organisations are very important, external observers	- feelings of customers or patients	Customer satisfaction	Communication→+ Transparency→+Coll	**Network integration**

that we need them to be able to objectively see what we are doing criticise what they think is not going well, and even voice out the feelings of customers or patients in the community. … We need to work with the stakeholders we need to also be transparent to them, we need to be able to make them understand what we need from the patient so that they can take the message to the patient as well as bring in feedbacks from customers or suppliers. …”. (94/148)	- work with the stakeholders - transparency - message to the patient	Collaboration Transparency Communication	aboration→+ Customer satisfaction	Closer relationship and communication with external stakeholders lead to improved medicine availability

MM45

ParticipantNumber-Quote number) "... variables in Phrase(s)" (word count in variables/total word count in causal statement)	Phrase(s) from participant quote denoting model variables	Interpreted model variables	Causal link between model variables (→=causal link, --||→=causal link with delay, +/- =positive or negative polarity)	Themes from participant quotes
MM45-01) "…we all work together …, once the orders are collected, the commercial department … the first thing they will do is to … check the credit status of … the customer. … they look at the customer receivable to understand whether the account is aged or not aged. …whether the account has exceeded its credit limit, if the account … is within the normal credit limits days …not gone beyond ninety days. … the account will be okayed to be approved for the next stage. …the customer cannot buy more than that, the customer has to make payment to create a space to raise more.	- orders are collected - check the credit status - exceeded its credit limit - gone beyond ninety days - customer receivable - cannot buy more -sales order	Customer orders Outstanding invoices Credit score Delay Account receivable Supply delay	Customer orders→+Outstanding invoices--//→+Account receivable→ -Credit score→-Supply delay→+Hospital medicine in transit→-Delivery→- Accounts payable	**Internal integration** Late payment by hospitals for medicines procured from suppliers' lead to delays in delivery of more medicines even when they make efforts to pay later.

… this sales order will be sent to a finance department for posting into customers who place an invoice the invoice will be sent to the in the account to the finance department. … the invoice then will be sent to logistic department for dispatching of the order of medicine to the customer. So, once It had been dispatch to the customer, an invoice will be given to the customer then is the job of the market review sales department that is commercial department to follow up with customers payment in conjunction with the finance department. So once the payment is … made, the commercial department will inform the account receivable officer who captures the customer payment and post it" (230/396)	- medicine to the customer - customers payment	Hospital medicine in transit Delivery Accounts payable		

MM45-02) "…we need to understand <u>their pattern of purchase</u>, … to know …have an idea of their consumption, I mean consumption pattern that is a technology in play that can help us have <u>first-hand information</u>, track their inventory. So, track their inventory to help us to prepare beforehand it will help us to know, <u>to buy raw materials</u> since we can see their consumption rate based on the information we have. So, we can do proper planning and …help us manage price fluctuation in my words, we have an idea of what our customer we <u>need in next six months</u> …we procure the raw material beforehand so that the customer's request will not take us by surprise. So, you've got the <u>technology</u> that can help us track their inventory, it will really improve the process". (134/175)	- their pattern of purchase - first-hand information - to buy raw materials - need in next six months - technology	Customer orders Information sharing Production Visibility Technology integration	Customer orders→+Information sharing→+Production→+Visibility→+Technology integration	**Information integration** When manufacturers know the trends in consumption of medicines, it helps them plan to deliver products to hospitals.

MM45-03) "… like our suppliers, we let them know, <u>have an idea of our inventory system</u> to …prepare beforehand. …before we have a re- order limit that we pass to them … to know and prepare our supplies. So we ensure that we don't <u>run out of stock</u> before stocks are replenished. Although we still have some of these challenges, some stock will get finished on time before we get restocked. This one our biggest challenge we are currently having. So what we need to do with our suppliers now is to make sure that they <u>understand our requirement</u> and so part and parcel of understanding our customer once we understand customer we know what we have, when is <u>going to be adjusted</u> …with this information, we can also	- have an idea of our inventory system - run out of stock - understand our requirement - going to be adjusted - smooth operation	Information sharing Stockout Customer orders Time to adjust inventory Production	Information sharing→-Stockout→-Customer orders→+ Time to adjust inventory→-Production	**Supplier integration** To ensure the manufacturers do not run out of raw materials for production, they share information with their suppliers and hospitals.

relate to our supplier so that there will be smooth operation". (138/214)				
MM45-04) "… they do need to understand our procurement pattern. So, them understanding our pattern depends also on our understanding of our customer requirement procurement pattern. Once we have this information, we'll be able to tell them when to restock us with raw materials. …from upstream, downstream …all need to have a kind of visibility of what this person is doing and what those people at the downstream too are doing". (69/150)	- procurement pattern - customer requirement - when to restock us with raw materials - visibility	Procurement Customer orders Desired production rate Visibility	Visibility →+Procurement→+Customer orders→+Desired production rate	**Customer integration** The hospital do not understand the extent that the manufacturers also work with their suppliers with information from the hospitals to make medicines available.

MM45-05) "Yes. how we <u>share information</u> is through marketing department, marketing department does that through detail and market and clinical presentation of our drugs, we do clinical presentation, and each representative are entitled to technical clinical motives in a month, the budget and also each representative are expected <u>to communicate</u> drug information to at least 20 doctors 10 pharmacist 10 nurses in a day ...". (64/109)	- share information -to communicate	Information sharing Communication	Information sharing→+Communication	**Information integration** Increasing communicatio n with suppliers allows product to flow in hospitals
MM45-06) "… so for our suppliers … we …present to them our requirement, what we need based on <u>what our customer want</u>. … prepared specification of what we expect based on what our customer needs, what kind of product our customer wants. So, we send specification to our suppliers to tell them	- what our customer wants - kind of expected standard that we want	Customer orders Desired production	Customer orders→+Desired production	**Supplier integration** raw materials needed for production relies on demand

… the kind of product/raw material that we need, the kind of expected standard that we want. All this has to do with what we learn from our customer what they need". (82/131)				information from hospitals.
MM45-07) "… digital information technology can help us understand customer sale requirement. So, we can track their inventory. …we can prepare a plan based on our understanding from our end. So, we have an idea or that information technology. Will help us look at this customer we can check their stock level or a particular product at any point in time from our end. So, when you know that you know when to restock them". (73/117)	-digital information technology - customer sale requirement - track their inventory - when to restock them	Information sharing Customer orders Visibility Delivery	Information sharing→+Customer orders→+Visibility→+Delivery	**Information integration** Planning of the manufacturing of medicines depends on the accuracy and timeliness of information from the hospitals.

MM45-08) "…we have thing like a <u>customer relationship management</u> applications yes you can also have it download on your Phone, you can have it on your WhatsApp, on your desktop, you can have it on your phone so that at a go you can actually check from your phone. What this <u>customer needs</u> to go into that customer relationship management application. We have the customer database information through that you can <u>communicate with your customer</u>. Yes, it also learns about and customer CRM software after application software. we have, one like Salesforce, many of them available". (95/96)	customer relationship management - customer needs - communicate with your customer	Supplier-Hospital Relationship (Trust) Customer orders Information sharing	Supplier-Hospital Relationship (Trust)→+Customer orders→+Information sharing	**Customer integration** Use of technology to manage customer relationships allows suppliers to meet customer needs.
MM45-09) "…<u>we set budget</u>, both product volume, volume budget, that's quantity budget. And also, revenue budget those are two ways we measure	- we set budget	Desired production	Desired production→+Manufacturer medicine inventory→-	**Internal integration**

the performance, how the product is performing volume wise, and how it's performing revenue wise. So we set budget weekly budget, we have daily budget, we have monthly budget, we have quarterly budget, and we have a half yearly budget and have annual budget. And we do review periodically review, weekly review daily review of further advance compared performance at any point in time against set that volume and revenue budget target.". (93/155)	- how the product is performing volume wise - performing revenue wise - review periodically - against set that volume and revenue budget target	Manufacturer medicine inventory Available funds Delay Desired production rate	Available funds--//→+Desired production rate	The manufacturers' ability to provide medicines can be constrained by budgets and available funding which can be worsened by delay in payment from hospitals.

MM45-10) "what you really get is for them to share information. …every month at the time of review, we usually have a meeting that representative from every department come together marketing that we do meeting together like a monthly we do monthly sales review, were all unit come and make presentation … the challenges of every unit will be discussed then our solution will be preferred. So if there is any issue to be identified on time …". (76/187)	- share information - monthly sales review - identified on time	Information sharing Selling delay	Information sharing--||→+Selling	**Internal integration** Keeping track of sales across the company helps in resolving bottlenecks.
MM45-11) "…Like most of these customers, most of these customers they buy more things that even …get damaged. So I think corporate social responsibility will help them a lot also support them because most of those things are wearing out on daily basis so	- buy more things - damaged - don't buy	Procurement Shrinkage Stockout	Procurement→+Shrinkage→+ Stockout	**Customer integration** The hospitals continue to buy medicines more than they need because

…that they don't buy all this things.”. (50/103)				of stockout fear leading to shrinkage from expiries.

SP43

ParticipantNumber-Quote number) "... variables in Phrase(s)" (word count in variables/total word count in causal statement)	Phrase(s) from participant quote denoting model variables	Interpreted model variables	Causal link between model variables (→=causal link, --||→=causal link with delay, +/-=positive or negative polarity)	Themes from participant quotes
SP43-01) "So the overall goal is <u>Universal health access</u>, which cannot be done without having medicines on the shelf. …So it's a <u>shared valued process</u>, our organization holds that everyone's idea is, at any point to have that <u>commodity delivered</u> at the facility when it's needed, at the <u>shortest possible time</u> here." (51 /82)	- Universal health access - shared valued process - commodity delivered - shortest possible time	Medicine inventory Strategic alliance Delivery Time delay	Strategic alliance--//→+Delivery--//→+ Medicine inventory	**Internal integration** Suppliers see their organisation as an extension of the hospital. On-shelf availability of medicines is paramount.
SP43-02) "…once we <u>understand the value</u>, then every other thematic area goes up and develop its own ideas on how to fit to that value then with <u>continuous improvement</u>, always on the	- understand the value - continuous improvement - you have a balance	Customer orders Fill rate	Customer orders→+Fill rate→+hospital-manufacturer relationship (trust)	**Customer integration** Having a supply chainwide

front burner, and always reviewing and getting feedback from the other end, in terms of both clients and also from suppliers. …<u>you have a balance</u> and then you can always review your services and optimize and get how best to deliver services." (73 /90)		hospital-manufacturer relationship (trust)		visibility is critical to meet customer needs.
SP43-03) "So, the basic frontline here is first data and <u>feedback data</u> is key all departments need to work on the key data elements that have been agreed as markers for <u>measurements of performance</u>, and then feedback at both ends from clients and suppliers to and that way you harvest information and you try to improve that is the basic point for us as an organization. First of all, you need that data <u>gives us visibility</u>, and then feedback." (78/93)	- feedback data - measurements of performance - gives us visibility	Information sharing Fill rate Visibility	Information sharing→+ Visibility→+Fill rate	**Internal integration** Constant communications with suppliers and customers support measure performance.

SP43-04) "… the structures in procurements has to do forecasting and quantification which is done and reviewed. So that is a marker first that gives us data to work on. It could be a direct call, it could be an email, and then we review. …once we see that there could be aberrations in quantities and supplies. So that is where the data team in supply chain is quite important as the they look at early warning signals and also look at the pipeline all the time to make sure that that can be averted. So basically … looking at visibility …your pipeline all the time." (105 /184)	- structures in procurements - forecasting and quantification - reviewed - gives us data to work on - aberrations in quantities - early warning signals -all the time - looking at visibility	Procurement Time to average orders Time reconcile inventory Customer orders Time to correct inventory Time delay Visibility	Procurement--//→+Customer orders→+Time to average orders→+Time to reconcile inventory→+Time to correct inventory--//→-visibility	**Customer integration** Even though teams engage in forecasting and quantification, use of early warning signals prevents error and improves performance

SP43-05) "…Without <u>feedback</u>, you don't have <u>visibility</u>. Without that visibility, you wouldn't know whether there are <u>gaps</u> or whether there are points of improvement. … when <u>data comes in from the client</u> to you can pick out early, <u>early warning signals</u> from those data to act on. And in that way, you can even help <u>serve the customer better</u> before he even gives a feedback. … we use our data to kind of bring out those elements that we feel could also <u>advance the customer</u>." (84 /154)	- feedback - visibility - gaps - data comes in from the client - early warning signals - serve the customer better - advance the customer	Information sharing Visibility Stockouts Customer orders Time delay Medicine inventory Customer satisfaction	Information sharing→+Visibility--//→-Stockouts→-Customer orders--//→-Medicine inventory→+Customer satisfaction	**Information integration** Delivery errors are detected from performance feedbacks in the system and used to improve customer satisfaction
SP43-06) "…It doesn't go much beyond <u>having visibility</u> and also getting the feedback. For us, <u>that's what works</u>. But as is now <u>continuous direct feedback</u>, and then getting your data and looking at	- having visibility - that's what works - continuous direct feedback	Visibility Customer orders	Information sharing--//→+ Visibility--//→-Stockouts--//→- Customer orders	**Information integration** Staff rely heavily on feedbacks and

it having someone designated who is who is trained on data analytics, and be able to pick out those early warning signals and gaps and bringing it out to the team so that all the teams look at it and make a decision." (75 /115)	- data analytics - early warning signals - gaps	Information sharing Time delay Stockouts		visibility to serve customers.
SP43-07) "…you have a critical stakeholder that maybe you have an MOU or something they have responsibilities to do, you help them and discuss currently, of how they can align to your own vision into the whole agreement, like what we call the RACI model, most of the time, you follow that strictly. And you continue to review that, and or even the performance of the RACI itself. There are critical stakeholders at the point of which who you have designated but their performance towards the overall goal is not giving you	- they have responsibilities - align to your own vision - always engaging - most of the time - at the point of - performance of the RACI - not giving you the percentages	Customer orders Communication Delay Fill rate Stockout	Customer orders→+Communication--//→+ Fill rate→-Stockout	**Network integration** A communication plan for all stakeholders is critical to ensure on-shelf availability of medicines.

<u>the percentages</u>, …to review that have the best that would contribute to that model for you and overall performance. So always engaging, <u>always engaging</u> with the partner or the donor, and align your goals and values is the best way for us...” (133 /176)				
SP43-08) “…the <u>information for our health commodities</u> comes from the warehouse management tool that is comprehensive enough. And then for what visibility our clients want to see. Is it the numbers in terms of <u>quantities that move out</u>. Basically, we do that mostly for our own scheme, an SOP for whatever data is it in facilities and the kind of <u>commodities</u>, the requests we have that are delineated by our own, we call it the <u>fulfilment system</u>. So we could …run a ticket on it, and then that pulls	- information for our health commodities - quantities that move out - commodities - fulfilment system - customer wants	Information sharing Shipment Medicine inventory Fill rate Customer orders	Information sharing→+Shipment→+ Medicine inventory→+Fill rate→+Customer orders	**Information integration** A digitally enabled fulfilment system ensures medicines are delivered to the hospitals on time.

off a facility of a region and depending on what the client or the customer wants, we can run that out and share." (111/123)				
SP43-09) "…we have our data team that looks at our stock movements, and then for the suppliers who [we] are working with us, we share that like, not in terms of actual numbers, but in terms of percentages that showed the movement of commodities and how we need them. And how in circle, they can fulfil that for us as suppliers over time, so we could do that quarterly and review and then have them submitted monthly." (76 /89)	- stock movements - in terms of percentages - commodities - over time - quarterly - monthly	Delivery Fill rate Medicine inventory Time delay	Delivery--//→+ Medicine inventory--//→+ Fill rate	**Supplier integration** Supplier relationship management system supports staff to fulfil customer orders.
SP43-10) "…according to RACI model …has its own unique way of sharing information. And somehow all the stakeholders prefer it in a different format, or in a different means somebody	- sharing information - not a one size fits all	Information sharing Stakeholder satisfaction	Information sharing→+Stakeholder satisfaction	**Network integration** Designing a communication

wants it by mail. Somebody wants it in hardcopy, so it is not a one size fits all." (47 /67)				plan that aligns with stakeholder needs improves stakeholder satisfaction.
SP43-11) "…we do not have better options to digital technology has come to stay digital technology has made things easier, has improved visibility at different points, you could be different parts of the world with digital technology, you can run supply chains, …remotely because of digital technology." (46/67)	- made things easier - visibility	Customer orders Visibility	Visibility→+ Customer orders	**Customer integration** Staff consider digital technology as the backbone of running operations successfully.
SP43-12) "…So it's, it's a digital meeting point where you have handshake, maybe from different platforms, that gives you a dashboard sort of thing that you could view all your departments and all your units, bringing it into the overall goal of the of the organization." (45/90)	- digital meeting point - dashboard - overall goal	Information sharing Visibility Fill rate	Information sharing→+Visibility→+Fill rate	**Information integration** Integrating information systems and managing

				performance achieves organisational goals.
SP43-13) "…our fulfilment system is sets in such a way that at each time where there are movements of stock, it gives a marker on what's the stock value of that particular product against a pre-set min-max that has been set for that particular product. So for each person running in the warehouse, …responsibility for that person, the officer to check what's the current value and reports to the supervisor who is in charge of that. So our fulfilment system automatically runs that, but it depends on the operator at the point to look at it and make critical decisions." (99 /120)	- fulfilment system - stock value - current value - critical decisions	Fill rate Distributor Medicine inventory in transit Time to reconcile inventory Shipment	Fill rate→- Distributor Medicine inventory in transit →+Time to reconcile inventory→- Shipment	**Internal integration** Reducing time delays with automation minimises supply delay and ensures hospitals get medicines on time.

SP43-14) "…Customers have needs. The supply chain has cost so bringing those two together balancing the cost and the needs of the customer is key. And that way you get it by getting direct feedback. Is your customer satisfied? What else does your customer need? …Does it fall in line with your supply chain costs? can you maximize that for the customer at the same cost, or there are trade-offs you can do even in terms of cost to serve the customer better. But once the customer is out there, and then the chance for feedback, you get that feedback work with your team for performance improvements." (106 /155)	- Customers have needs - balancing the cost and the needs - customer satisfied - supply chain costs - cost to serve - performance improvements	Customer orders Available funds Customer satisfaction Supply chain costs Cost to serve Fill rate	Customer orders→+Available funds→- Supply chain costs→+Cost to serve→- Fill rate→+Customer satisfaction	**Customer integration** Suppliers measure hospital satisfaction with their services. This service does not extend to the patient.

APPENDIX X: INTERVIEW ANALYSIS FOR CASE B

Interview Quotation Analysis for Case B

IS07

ParticipantNumber-Quote number) "... variables in Phrase(s)" (word count in variables/total word count in causal statement)	Phrase(s) from participant quote denoting model variables	Interpreted model variables	Causal link between model variables (→=causal link, --||→=causal link with delay, +/-=positive or negative polarity)	Themes from participant quotes
IS07-01) "to make medicines available in the hospital, the pharmacy department has always set the pace by coming up with the list of drugs, needed for the hospital. … an application written to the chief executive for approval to such drugs and from the chief executive the approval is usually sent to the procurement unit to commence procurement. … procurement normally gives two weeks for the supply. The pharmacy department receives the medicines after checking, report is generated by the store officer to the2 chief executive for consideration of payment to the supplier". (92/138)	- medicines available - list of drugs - procure - payment	Order fulfilment Medicine inventory Order procurement Paying suppliers	Order procurement→+ Medicine inventory→+ Order fulfilment→+Paying suppliers	**Internal integration** Getting medicines and paying suppliers is the target of the revolving fund.
IS07-02) "to improve the relationship among the interdepartmental teams is for other departments to understand the request generated by the pharmacy. Account also needs to understand that	- relationship - request generated - cost effective	Teamwork Order procurement Purchase price	Teamwork→+Order procurement→- Purchase price→- Order fulfilment--//→- Paying suppliers→+	**Internal integration** There is no teamwork as

these products are cost effective. … after specified period of time suppliers need to be paid. To improve inter-relationship, what pharmacy sends as a request should be respected and they should understand if there's any ambiguity procurement should make effort to understand with pharmacy department for clarity, ...purpose. after the product has been supplied, accounts section … not delay the payment of those companies because delay in their payment will affect future supplies. The doctors and nurses should let us have feedbacks about drugs if they are giving the intended reason for procurement. If not, pharmacy will need to make re-adjustments at the next procurement by re-considering a different supplier". (136/185)	- period of time - delay - supply is made - paid - respected - affect future supplies - re-adjustments	Delay Order fulfilment Paying suppliers Staff satisfaction Supply delay Adjusting medicine on order	Supply delay→-Staff satisfaction→+Adjusting medicine on order	pharmacy request are not respected and prioritised leading to dissatisfaction. Payments of suppliers are delayed resulting in stockouts.
IS07-03) "… the relationship with patients is usually between the pharmacy department, the doctors and nurses…. the relationship has been cordial, we ask for feedbacks. We counsel the patients on how to take their medicines and how to equally preserve their medicines at home. We will also encourage them to come back if there is any issue with their medication. …we … channel the problems. if the	- relationship with patients - feedbacks - counsel - call the attention preserve	Hospital-customer relationship Communication Medicine quality	Communication→+ Hospital-customer relationship→+Medicine quality	**Customer integration** Staff inform suppliers of medication problems and ensure patients safety.

problems are from suppliers. We can call the attention of the suppliers". (77/101)				
IS07-04) "… we have limited suppliers being a mono-specialist hospital. But we are always in contact with them. … for those products that are not fast-moving, it is the duty of the suppliers to detail the doctors, they get feedback from the doctors. For getting medicines into hospital, the policy has changed a bit now with the introduction of procurement units. This issue has already caused a little rift and has tainted the relationship. The procurement department needs to understand why the pharmacy is making reference to particular medication. … with the coming of procurement, we're really trying to build the relationship where because our procurement department staff are not medically related. they are neither pharmacist, doctors or nurses. They are administrative staff. So their knowledge about drugs is very limited. So, we have always encouraged that procurements should consider obtaining these drugs from the source, suppliers that are the makers or the major distributors because that will ensure that the	- contact - detail the doctors - procurement - a little rift and has tainted the relationship - build the relationship - particular medication - about drugs is very limited - any issue - lately	Communication Customer orders Order procurement Teamwork Hospital average order Time period for reconciling inventory Medicine quality delay	Communication→+Customer orders→+Order procurement→+ Hospital average order→-Teamwork→-Time period for reconciling inventory--//→-Medicine quality	**Supplier integration** Communication friction between the teams prevents stocking of adequate medicines at the right time.

products are coming from the right sources and if there's any issue, of course we know where to face and lately, procurement has started giving us a listening ear to that direction". (192/209)				
IS07-05) "There are many ways to improve relationship with patients, …if patients come to the hospital, no matter how the doctor treats them, if their drug needs are not met, the patients will certainly, leave the hospital unhappy. to improve relationship with patients is the speed to which pharmacy procurement request should be attended to by the management …. the procurement unit should equally prioritize payments of drugs. The drugs will be available, and the patients will be happy and it will improve relationship between the team and the patients". (89/109)	- relationship with patients - hospital unhappy - speed - payments - available	Hospital-customer relationship (trust) Customer satisfaction Time to average orders Paying suppliers Medicine inventory	Time to average orders→- Medicine inventory→+ Paying suppliers→+Hospital-customer relationship (trust)→+ Customer satisfaction	**Customer integration** Delaying procurement and paying suppliers reduces trust and customer satisfaction
IS07-06) "…improving relationship with supplier is by prompt payment. Almost every supplier is ready for supplies, they're ready for business, but what is really discouraging them is lack of prompt payment supply made. Improving relationship with critical stakeholders is adequate funding on the	- payment - ready for supplies - lack of prompt - adequate funding	Paying suppliers Medicine inventory Delay Government funding	Government funding--//→+ Paying suppliers→+ Medicine inventory	**Cash flow integration** Increasing funding to hospitals helps in payment of suppliers to deliver more medicines.

part of government or the facility. In this facility,”. (51/56)				
IS07-07) “… all the problems are interrelated because they're centred around funding, government can improve the working relationship by increasing funding of medicines and medical instruments. Recently we had donations for COVID-19… that has really helped, even though we don't have an isolation centre, but it has certainly improved the relationship with patients. … supplies from donors and partners, and some government agencies really improved relationship with the hospital and the patient”. (71/92)	- funding - medicines - relationship with patients - relationship with the hospital and the patient	Government funding Medicine inventory Customer satisfaction Hospital-customer relationship	Government funding→+Medicine inventory→+Customer satisfaction→+Hospital-customer relationship	**Network integration** The hospitals need more funding even with markups from revolving fund, particularly during the pandemic which increased medicine demand.
IS07-08) “During dispensing counselling, we share information related to the medication the patient is receiving. the information includes a description of the drug, we are giving the patient and what the patient expects from the drug. the possible side effect of the drug. and what to do in case of such side effect. we describe the best way of storing these medicines at home to maintain its integrity. … we check weekly to see whether those being stored well. those about to expire are exchanged with other ones, for the	- share information - integrity - expire - manually	Share information Medicine quality Shrinking and expiring inventory delay	Share information→+Medicine quality--//→-Shrinking and expiring inventory	**Information integration** Sharing information with patients improves compliance and reduces wastages.

doctors. … we share information with them and that has always been done manually not electronically”. (105/197)				
IS07-09) “…information sharing concerning stock level, drugs about to expire, we share that information with our suppliers. for drugs about to expire, we call on the suppliers to inform them about the expiry date, so that they can step up their detailing to the doctor's or if possible like what I’ve always demanded from them is outright replacement with products that have far date but we don't wait until when it’s just about to expire, we give them information like five to six months ahead, particularly if the stock level is quite high. But for the other stakeholders within the hospital. We normally raise our request once the stock level has depleted and what is left is about 25% of earlier stock. So, we raise another requisition and forward it to the management for replenishment or possible procurement, we do it manually and not electronically”. (144/160)	- information sharing - step up their detailing - five to six months ahead - procurement,	Information sharing Selling Delay Order procurement	Information sharing--//→+Selling→+Order procurement	**Information integration** Procurement increases when information is aligned within the hospital.
IS07-10) “… even though we've started in our facility, we're yet …reach the apex of it but in my opinion, the digital	- digital technology	Digital technology	Digital technology → +Capacity	**Information integration**

technology for making medicines available is a sure way that information concerning stock level, expiries and reorder can be easily accessed and make use of. … we've not used any type here. the only thing we have is a glorified E-pharmacy where the prescriptions are received from the doctors and other healthcare members. It's also intended to guide us in our inventory management, even though the networking is still without a software technology for making medicines available ...". (99/131)	- information - reorder - glorified - without a software	Information sharing Order procurement Staff satisfaction Capacity	→+Information sharing→+Order procurement→+Staff satisfaction	Technology helps in procuring medicines and the staff are disappointed at their level of digital transformation.
IS07-11) "…will measure performance in terms of number of … the percentage of patients that meet their drug needs in the hospital. the total number of patients that visit the hospitals and how many of them, at least were able to access let's say, upto 80-90% of their drugs needs. That is how i'll measure my own performance". (57/64)	- meet their drug needs - upto 80-90%	Fill rate Desired fill rate	Desired fill rate→-Fill rate	**Internal integration** Increasing desire to improve fill rate puts pressure on the system and fill rates drop.
IS07-12) "request for making drugs available in the hospital, always starts from the pharmacy department. We need to really be on our toes to ensure that the order levels are being attended to when due. pharmacist should be able to know what has attained a reorder	- order levels - procurement - processes	Hospital average orders Order procurement Process integration	Hospital average orders→ Process integration--//→+Order procurement→-Paying suppliers →-Supply delay →-Order	**Supplier integration** Paying suppliers is critical for continuous

level and make a quick response to that. …the next place where we have issues is the procurement, the procurement unit needs to understand that these are specialised products that are intended to save lives as such their processes should not take much time. the next stakeholders are the suppliers, sometimes suppliers could be given awards for supply of medicines, and they take a long time to supply. …we as pharmacy, we may not have much power about that, but the stakeholders and our suppliers need to also respond in good time in supplying such medicines. … if the suppliers are paid when due… i think they will equally reciprocate when they are called to supply next time". (163/198)	- not take much time - take a long time to supply - power - paid when due - reciprocate	Delay Supply delay Staff satisfaction Paying suppliers Order fulfilment	fulfilment→-Staff satisfaction	replenishment of medicines.
IS07-13) "We hardly receive donations from the donors out there, but for government, improved funding. for regulators, there are some products that accessing them sometimes, could be difficult because of regulations concerning the importation and the use of such drugs. There needs to be collaboration between facilities, and regulators especially for products that are known to be used by a particular facility. … the civil society organisation	- improved funding - regulations - collaboration - made available	Government funding Medicine production Collaboration Medicine inventory		**Network integration**

have a role to play, some of them might not be members of the healthcare teams but interaction with them through meetings could help ensuring that ensuring that these medicines are always made available to the majority of the public". (106/120)				

IS22

ParticipantNumber-Quote number) "... variables in Phrase(s)" (word count in variables/total word count in causal statement)	Phrase(s) from participant quote denoting model variables	Interpreted model variables	Causal link between model variables (→=causal link, --‖→=causal link with delay, +/-=positive or negative polarity)	Themes from participant quotes
IS22-01) "the pharmacy dept has the sole responsibility to <u>select the drugs</u> to be procured and the procurement unit makes sure there's compliance with the Public <u>Procurement Act</u>. … the accounts development process <u>payment</u> and the contractors are paid for the <u>services provided</u>". (42/56)	- select the drugs - Procurement Act - payment - services provided	Average order rate Order procurement Paying suppliers Order fulfilment	Average order rate→+Order procurement→+Paying suppliers→+Order fulfilment	**Internal integration**
IS22-02) "when dealing with the patient as far as <u>drugs</u> are concerned is the responsibility of the pharmacy dept because other players in the team like accounts and procurement don't deal directly with patients. The pharmacy department <u>dispenses</u> the drugs and provides for the necessary patients…". (45/68)	- drugs - dispenses	Medicine inventory Selling	Medicine inventory→+Selling	**Customer integration**
IS22-03) "…the pharmacy department make drug selection to select which <u>drug to procure</u> because they deal directly with the patients and the prescribers. … As professionals, they know which brands have been tested	- drug to procure - cost effective -lists	Order procurement Sell price Average order rate	Average order rate→+Order procurement→+ Order fulfilment→- Sell price→-Paying suppliers	**Internal integration**

and certified as efficacious, safe and comparatively cost effective. … then procurement is provided with the lists of the selected products that are needed. the procurement unit work with the contractors and accounts comes in when the supply has been effected. when it comes to the issue of payment, … account has the sole responsibility of processing payment". (90/123)	-supply - payment	Order fulfilment Paying suppliers		
IS22-04) "particularly both procurement units and accounts department will facilitate patient satisfaction by respecting the responsibilities of the pharmacy dept. … whatever selection the pharmacy does should be respected by the procurement and whatever the procurement unit has ordered for, Accounts department should facilitate payments to the contractor and that will satisfy the patient's needs. Because it is only when the three major players work together that drugs will be available for the patients to access". (75/87)	- patient satisfaction - respected - payments - work together - drugs will be available	Customer satisfaction Staff satisfaction Paying suppliers Teamwork Medicine inventory	Teamwork→+Medicine inventory→+ Staff satisfaction→+ Paying suppliers→+ Customer satisfaction	**Cash flow integration**
IS22-05) "… the only way to improve the relationship with the suppliers is by sticking to the principles enshrined in the Public Procurement Act. if those provisions are strictly adhered, then I don't think the facility will have any	- relationship - problem in terms of supply	Hospital supplier relationship (trust) Supply delay	Hospital supplier relationship (trust)→- Supply delay	**Supplier integration**

problem in terms of supply with their contractors". (45/56)				
IS22-06) "… when there is harmonious working relationship among … the team particularly pharmacy department, Accounts Department and procurement, that will a long way in dealing with whatever challenge in terms of supplies of drugs and hospital consumables. When dealing with stakeholders like donor agencies, or partners, … the rights channel should be followed if the supplies expected from those partners are drugs, then the pharmacy has to be given the chance to handle the professional aspects, particularly when the donation comes from outside country. … the other key players have to allow the pharmacy department to decide based on the guidelines for drug donations…". (103/168)	- harmonious working relationship among … the team - supplies - professional aspects - drugs to receive	Teamwork Order fulfilment Reconciling inventory	Teamwork→+Order fulfilment→+Reconciling inventory	**Network integration**
IS22-07) "…we are here because of the patient and whatever efforts the pharmacy department makes is to satisfy the patient. Patients are entitled to information about drugs dispensed to them…". (29/155)	- satisfy the patient - information	Customer satisfaction Information sharing	Information sharing→+ Customer satisfaction	**Information integration**

IS22-08) "… when stock is depleted up to 75%. When you have 25% of your drugs left, you must raise a red flag to the persons responsible for supplies…. the pharmacy store does that through notifying the head of pharmacy. It is the responsibility of the head to convey that notification to the management so that procurement process will be initiated such that the drugs come before supplies are exhausted. …For drugs that are close to expiry maybe 3 months to expire, a notice will be issued to departmental management and if there are ways to move the drug out so that it can be consumed before the expiry date. …". (108/149)	- depleted - procurement - consumed	Stockout Order procurement Customer order	Customer order→+ Order procurement→- Stockout	**Supplier integration**
IS22-09) "…to suppliers, … information sharing is between pharmacy department and procurement. Pharmacy Department shares the information on what they need and the specifications. The procurement shares with the suppliers or contractor, the specifications and the expiration, as a policy of the hospital we only receive medicines of not less than 2 years to the expiry date. … to patients, … when the pharmacy is designed in such a way to facilitate a one-on-one interaction	-information sharing - specifications -2 years to the expiry	Information sharing Desired delivery Shrinking and expiring inventory	Information sharing→+Desired delivery→+Shrinking and expiring inventory	**Information integration**

between the pharmacy staff and the patient, it will go a long way in passing … information …". (91/309)				
IS22-10) "… when you're dealing with stakeholders, … donors, it's not the exclusive role of pharmacy dept, it involves different departments of the hospital and the hospital management. … the pharmacy department has the responsibility of passing across the necessary information about the drugs or any hospital consumable that is under their custody, such that the partners or donors that give drugs, the management is fully informed about the drugs and that is the sole responsibility of the pharmacy dept because they have professionals …". (82/94)	- different departments - information - drugs - give drugs	Teamwork Information sharing Medicine inventory Order procurement	Teamwork→+Information sharing→+Medicine inventory	**Network integration**
IS22-11) "we are in the digital era now, … if we … use of electronics means in carrying out our work, it will go a long way in helping us avoid certain issues for example, stockouts. … the use of ICT, the pharmacist in charge of stores can comfortably monitor stock levels in other units of pharmacy dept. … He will also consider his own stock based on the quantities they are requesting and based on their consumption trend. he will know whether to inform management of the hospital for fresh supplies. it will minimise a lot of errors.	- digital era - stockouts - stock levels - quantities - consumption - fresh supplies - errors	Digital technology Stockout Medicine inventory Average order rate Customer order Order fulfilment Shrinking and expiring inventory	Digital technology→+ Average order rate→+ Order fulfilment--//→+ Medicine inventory→- Stockout→-Customer order→- Shrinking and expiring inventory→- Staff satisfaction	**Information integration** Using technology reduces errors and fatigue leading to staff satisfaction and customer satisfaction

… electronic connection between the pharmacy, the consulting room, medical records the laboratory …by that human error will be minimized and it will facilitate recordkeeping because something that you have to do manually, if it is done electronically, it reduces fatigue and forgetfulness”. (141/187)	- manually - fatigue and forgetfulness	Delay Staff satisfaction		
IS22-12) “… I appreciate the use of technology because what I saw is that the central pharmacy store is fully aware of what is happening in that facility. ...if they request for an item and based on the consumption trends is considered to be too high, the store pharmacist will be able to detect that and reduce the quantity from the comfort of this office to what is optimal. The pharmacies doesn't have to go to the consulting room to see the prescriber he can raise concern from his office and they will look at it together and agree on what to do and the patients will not be stressed out going to and from the pharmacy to the consulting room. …”. 121(/150)	- what is happening - request for an item - consumption trends - request for an item - reduce the quantity - have to go - patients will not be stressed out	Visibility Customer order Average order Medicine inventory correction Delay Customer satisfaction	Customer order--//→+Visibility→+ Average order→- Medicine inventory correction→+ Customer satisfaction	**Customer integration** Visibility reduces time to correct inventory and increase customer satisfaction by reducing lead times.
IS22-13) “… it can never be 100%. Based on my experience, i will score the organization 75%. … when it comes to issues of drugs or medical consumables… pharmacy department	- score the organization 75% - cannot satisfy	Fill rate Stockout	Teamwork--//→+Medicine	**Customer integration**

cannot satisfy the needs of the patients unless products are made available in the pharmacy and that is the sole responsibility of the other depts, even procurement places an order for a contractor to supply, then that can only be sustained when the contract gets paid as at when due and that is the responsibility of the accounts dept. …the procurement, the accounts, the pharmacy, all of them have the responsibility to work together towards satisfying the needs of the patient…". (109/154)	- products - gets paid - when due - work together - satisfying the needs	Medicine inventory Paying suppliers Delay Teamwork Customer satisfaction	inventory→-Stockout→-Paying suppliers→+ Fill rate→+Customer satisfaction	

MM47

ParticipantNumber-Quote number) "... variables in Phrase(s)" (word count in variables/total word count in causal statement)	Phrase(s) from participant quote denoting model variables	Interpreted model variables	Causal link between model variables (→=causal link, --‖→=causal link with delay, +/-=positive or negative polarity)	Comments
MM47-01) "In conjunction with our importers, … they send us adequate information of data on the supplies that we need and the quantity, which actually do goes through NAFDAC, that rations whatever you produce or stuff like that. … with their support from the international suppliers, we make arrangements of product materials that we need, they make them available and due to some logistics, there might be some delay in receiving the raw materials which can actually affect the costumers too receiving the finished product." (84/98)	-In conjunction with our importers - send us adequate information of data - supplies that we need - and the quantity - make arrangements of product materials - whatever you produce - make them available	External integration Information sharing Desired production Medicine inventory holding Production	External integration --//→+ Information sharing→+ Desired production →+Medicine inventory holding--//→- Production→- Delivery--//→+ Manufacturing cycle time→- selling	**Supplier integration** Delays from bureaucracy and receiving raw materials due to logistics issue prevents on time production and leads to medicine stockouts in the hospitals

	- there might be some delay - affect the costumers too receiving the finished product	Delivery Manufacturing cycle time selling		
MM47-02) "Proper planning ahead, … quarterly, so you know by this time of like a first quarter, second quarter, third quarter it depend on how the company wants to differentiate that will make them have proper preparation down for in case there is any shortage of product, at least you will make some plans that by this kind of quarter, these are the products we need, with that we can beat the challenge of scarcity of product." (76/83)	- Proper planning ahead - quarterly - shortage of product - products we need - beat the challenge of scarcity of product	Time to average and reconcile orders Delay Medicine stockout Desired inventory Work in process correction	Time to average and reconcile orders--//→+ Medicine stockout →- Desired inventory--//→- Work in process correction	**Internal integration** Inadequate forecasting and quantification of medicines lead to shortages.

MM47-03) "Once there is <u>proper preparation quarterly</u>, we will know <u>what product to do.</u> So with that <u>information which has been gathered over years</u>, we get enough <u>rough sketch of preparation down</u> that ok let us produce this amount of product down, by that we will be able to <u>satisfy our costumers</u> based on <u>their need</u>." (55/59)	- proper preparation quarterly - what product to do - information which has been gathered over years - rough sketch of preparation down - satisfy our costumers - their need	Time to average and reconcile orders Production Information sharing Medicine inventory correction Customer orders Desired order rate	Time to average and reconcile orders→- Desired order rate→+ Production→+ Customer orders→ +Information sharing→- Medicine inventory correction	**Information integration** Demand and procurement planning helps satisfy customer needs.
MM47-04) "<u>Regular information</u> on what, because <u>you can't actually predict</u> … environment … condition or weather or health issues. So regular information's like <u>documentation of what is going on</u>, so that will guide our thoughts on what	- Regular information - you can't actually predict - documentation of what is going on	Information sharing Process integration	Information sharing--//→+ Process integration →+ Visibility→+ Production rate →-Adjust medicine in transit	**Information integration** Sharing information increases

we the producers will prepare for in … a situation whereby it is uncontrollable or something we've not seen before, we have to re-strategize to beat whatever is occurring within the health system." (69/75)	- producers will prepare - uncontrollable - we've not seen - re-strategize	Production rate Delay Visibility Adjust medicine in transit		visibility and reduces the pressure to continuously adjust production.
MM47-05) "Based on their request, they give us orders which is LPO's, we get them if the materials are available we produce them, some we produce them before the LPO's get out, we work on it before the information get to us, so once it gets to us we give the suppliers as soon as possible. The delay in supply might affect the health community, we work with information … create fast delivery to help the society." (76/78)	- Based on their request - materials are available - produce - before the information - as soon as possible	Customer orders Medicine inventory holdings Production Information sharing Delay	Customer orders --//→- Medicine inventory holdings→- Information sharing→+ Production→- Supply delay→+ Delivery→+ Fill rate	**Information integration** Adequate information sharing increases medicine fill rate by reducing supply delay and

	- delay in supply - delivery - help the society	Supply delay Delivery Fill rate		improving production rates.
MM47-06) "Logistics is the number one, because of the terrain where we work .... Once insecurity issues and the likes, if logistics can be properly handled, I feel it will put us back in our games like fast delivery. In some countries instead of using logistics by road, they use drones' deliveries, so with that we don't need to risk anybody's life or time. We just have some drone machines to control then deliver the drugs to each and every area that even humans cannot go to. I wish they can work more on logistics in terms of future	- Logistics - fast delivery - insecurity issues - risk anybody's life or time - deliver the drugs - drones' deliveries - logistics by road - I wish they can work more on logistics	Delivery Delay Fill rate Delay External integration	Delivery→+ Fill rate--//→+ External integration	**Customer integration** Integrating instant medicine delivery using drone technology improves fill rate

of logistics not just the usual conventional logistics." (106/131)				
MM47-07) "Naturally, the importers, raw supply providers I feel there should be like a set goal of understanding because the economy of the country …, by this quarter we will pay you and these are the materials we will need, even without change in dollar, because change in dollar affect a lot of things and once there's a change, the supplier might be greedy …. You know business is about profit, it's not about friendship or family. So everybody want to maximize every way they can make profit, so if there's an agreement that okay, this are the things we want and these are the payment upfront, … it will help a lot, so that the	- raw supply providers - set goal of understanding - by this quarter - we will pay you - materials we will need - change in dollar - greedy - profit	Desired production rate Credit score Delay Weeks of payables Desired production Purchase price Opportunism Mark up	Credit score →+ Desired production rate→+ Desired production--//→+ Weeks of payables→+ Opportunism→+ Purchase price→+ Mark up→- Cash collected→+ Production rate--//→+ Productivity	**Supplier integration** Fluctuating dollar exchange rate encourages opportunism and raw material suppliers increase their prices to make more profit. When prices increase, selling of products decrease and

economic situation won't affect the <u>productivity</u> of the company." (124/174)	- payment upfront - help a lot - productivity	Cash collected Production rate Productivity		staff motivation decreases.
MM47-08) "It all goes back to the economic situation, everybody wants to maximize every little chance to make <u>profit</u> and most of the partners are stakeholder and shareholders they are the ones that <u>make decisions</u> at the board they can decide okay this thing is not favouring us and we don't want to do this anymore. By that, it will <u>affect a lot of people</u>." (64/92)	- profit - make decisions - affect a lot of people	Mark up Production rate Productivity	Mark up→- Production rate→+ Productivity	**Internal integration** Increasing the purchase price of raw materials decreases the rate of production and productivity of manufacturers

MM47-09) "We run promotions for our customers, once the costumers are interested in this product then they go for it. Then for the people that supplies us with raw materials we tell them how lucrative this might be via emails or telephone calls. Once we pass information across they make the raw materials available." (53/93)	- promotions - go for it - via emails or telephone calls - pass information across - raw materials available	Selling activity Customer orders Technology integration Information sharing Production rate	Selling activity →+ Customer orders→+ Information sharing→+ Technology integration→+ Production rate	**Customer integration** Promotion increases sales of medicines and boost production for manufacturers.
MM47-10) "Like I always say the rationality should be the basics of every information shared, rationality and effects of it on the community because that is the essence of health system providing a better living for the people living in the community. so if there's rationality in place … everybody should be fine with whatever it is on ground." (58/65)	- information shared - whatever it is on ground	Information sharing Medicine inventory	Information sharing→+ Medicine inventory	**Information integration** Enhancing information sharing with suppliers increases medicine availability

MM47-11) "It is the best and the safest way for me because the world is advancing, and people are moving fast into technology. We will always support the idea of investing on technology that can make things available, like in drug issue … if we cooperate in this kind of technic into medicines like this kind of areas that we have that is insecure, where the driver will be scared and say I don't want to go to the area. It won't delay or tamper with the logistics. …once we invest in technology in terms of pharmaceutical supply it will help a lot." (102/213)	- technology - drug - insecure - tamper with the logistics - help a lot	Digital technology Medicine inventory Delay Delivery Fill rate	Digital technology --//→+ Medicine inventory→+ Delivery→+ Fill rate	**Information integration** Alignment of technology with suppliers improves medicine availability and fill rate.

MM47-12) "I will say seventy to eighty percent <u>medicine availability</u>. Like proper <u>planning</u>, proper <u>information</u> and technology involvement those are the key areas I am sure that once these areas are touched there will be a <u>smooth relationship</u> within these three categories." (41/41)	- medicine availability - planning - information - smooth relationship	Fill rate Time to average and reconcile orders Information sharing Manufacturer-stakeholder relationship (Trust)	Fill rate→- Time to average and reconcile orders→- Information sharing→+ Manufacturer-stakeholder relationship (Trust)	**Information integration** Sharing information improves fill rate and trust in the systems.

APPENDIX XI: INTERVIEW ANALYSIS FOR CASE C

Interview Quotation Analysis for Case C

IS11

ParticipantNumber-Quote number) "... variables in Phrase(s)" (word count in variables/total word count in causal statement)	Phrase(s) from participant quote denoting model variables	Interpreted model variables	Causal link between model variables (→=causal link, --‖→=causal link with delay, +/-=positive or negative polarity)	Themes from participant quotes
IS11-01) "… we have the standard procedures based on the federal government financial regulations and procurement policies. The committee is responsible for the procurement of medicines according to the Procurement Act of the Republic of Nigeria, the tender committee is responsible for procurement of medicines. The user department generates the list for procurement into the store. … having generated the list and quantify the medicine, the other members of procurement unit are called in". (72/128)	- financial regulations - procurement of medicines - list - quantify	Cash at bank Order procurement Customer order Time period for averaging orders	Customer order→+ Time period for averaging orders→+ Order procurement→+ Cash at bank	**Internal integration** Abiding by the by financial regulations ensures that there's money available to procure medicines.
IS11-02) "…we cannot do this procurement without the procurement unit. …the accountant will give us the financial implication. Before you procure, there must be availability of funds. we send out the advert and the	-procurement - financial implication - availability of funds	Order procurement rate Cash at bank Weeks of cash at bank	Visibility→+Weeks of cash at bank-→+ Cash at bank→+ Desired delivery→+ Order procurement rate	**Cash flow integration** Transparency in cash flow for medicines

bidding system is open, robust and transparent". (40/76)	- advert - open, robust, and transparent	Desired delivery Visibility		increases medicines inventory as more medicines can be procured.
IS11-03) "…Now we use e-system. … is to use IT and innovations using excel spreadsheets to carryout bidding process. Information technology is very important, before it used to be a manual process … now we use spreadsheets and within some minutes you can see the summary of everything can be generated. Availability of funds can improve the procurement system". (53/62)	- e-system -bidding process - Availability of funds	Digital technology Order procurement Cash at bank	Digital technology →+Order procurement→+Cash at bank	**information integration** Technology enables procurement with faster flows of prescription orders and cash flow with real-time collection process.
IS11-04) "…Whatever you want to buy, you must make sure that you buy it to the needs of the patients. We have two segments of patient in this hospital, we have out-patient we have in-patient, those on admissions. And we've brought out a system where pharmacists improve accessibility of medicines to patient ... led introduction of the unit dose dispensing system, which is a way of supplying drugs try to the bedside of the patient, counselling patients on proper use of these medicines. Before we do window dispensing system, but today we are using various in cubicle	- needs of the patients - improve accessibility - unit dose dispensing system - counselling - see a patient - give the patient medicines	Customer orders Fill rate Order fulfilment Information sharing Visibility Selling	Customer orders→+ Order fulfilment→+ Fill rate →+Visibility→+ Information sharing→+ Selling	**Customer integration** When patients get their medicines filled, they will share information with others and more patients will come to the hospital leading to increase in sales.

system where you can see a patient and give the patient medicines". (108/139)				
IS11-05) "Emphasis is on pharmaceutical care which is responsible for provision of drug therapy to achieve a definite outcome that improved quality of life of a patient. You can only achieve that by giving information. we also interact with our colleagues who are medics, nurses, doctors and other health workers in the hospital. we have drug and therapeutic committees, a body that's responsible for production of the list of items to be procured in the hospital. if you procure and the doctor does not write it, the medicine will expire. we must give adequate information to the doctors, … to the nurses because they are the ones that are very close to the patient. … to the management because if the management does not approve the procurement of medicines". (128/139)	- provision of drug therapy - outcome - giving information - list of items - expire - write it	Order fulfilment Fill rate Information sharing Order procurement Shrinking and expiring inventory Customer order	Customer order→+ Order procurement→+ Information sharing→- Shrinking and expiring inventory→- Order fulfilment→+ Fill rate	**Information Integration** Sharing information with the hospital team ensures medicines are procured and helps doctors to know what to prescribe to patients reducing shrinkages and expiries leading to better fill rates.
IS11-06) "Management must be aware the cost implication of these medicines to be able to evaluate problems where there's paucity of funds can become a problem. In recent times we have problems with availability of funds and management has to make sure that they work around the clock to ensure that	- cost - paucity of funds - problem - recent times - work around the clock	Purchase price Accounts payable Stockouts Delay	Purchase price→+Accounts payable--//→- Cash at bank→- Stockouts→+ Information sharing→- Visibility→+Network integration	**Network integration** Problems with cash collection depletes cash at bank. When hospitals are unable to pay suppliers,

funds become available. so if information does not get to them. the condition cannot be resolved. These are the interconnectivities between we the provider, the users and of course our customers our clients in the hospital. information is very robust, we call it a multidisciplinary information approach". (97/97)	- problems with availability of funds - information does not get to them - interconnectivities - multidisciplinary	Cash at bank Information sharing Visibility Network integration		medicines will be stocked out making it difficult for all stakeholders.
IS11-07) "…we advertise, we don't need to know you before you can participate in the procurement process. there's a procurement law and financial regulations that is fully followed. You will follow it in the sense that yes, if we need drugs, you prepare this as we have just finished now". (49 /67)	- advertise - procurement process - need drugs	Desired delivery Order procurement rate Medicine inventory holdings	Desired delivery→+Order procurement rate→+Medicine inventory holdings	**Supplier integration** Medicines are supplied to hospitals that pay outstanding bills.
IS11-08) "… when the suppliers have quoted all of them, we now open transparently and look for the lowest bidder. … we'll pick the lowest and these are the relationships we have with the suppliers. they bid and we award based on the bid". (43/109)	- quoted all - lowest bidder - relationships	Desired delivery Purchase price Hospital-manufacturer relationship (trust)	Purchase price→-Desired delivery→+Hospital-manufacturer relationship (trust)	**Supplier integration** Buying from suppliers is based on price and trust.
IS11-09) "…the departments will improve relationship with patient by making the need of the patient available, not only available but	- relationship - available	Hospital-customer relationship (trust) Fill rate	Hospital-customer relationship (trust)→+Fill rate→+	**Customer integration**

accessible by the patient. …the relationship is more robust by availability of the service, the accessibility of the service and affordability of the service. And that's why we ensure open bidding where our patient can get affordable, medicine, not only affordable but quality medicine …, but really accessible. … we have pharmaceutical care for patients can to get access and also to create quality information". (84/188)	- accessible - affordable - quality - quality information	Customer satisfaction Sell price Medicine quality Information sharing	Customer satisfaction→+ Information sharing→+ Medicine quality→-Sell price	Getting affordable medicines of quality increases trust and customer loyalty.
IS11-10) "… paying suppliers … promptly… because that payment delay is also a cost implication on the patient and the supplier. when you pay promptly, when they know that they're going to get their money on time. There overhead will also reduce. … government to reduce tax rebate and stamp duty which are also making medicines expensive. …. if supplier supplies drugs and perhaps, he borrowed this money from the bank and two months to one year, you did not pay the supplier, the company can be liquidated the collateral of the company will be in trouble. … payment is the core". (100/219)	- paying suppliers -promptly - cost implication - overhead - expensive - borrowed this money - two months to one year - did not pay - liquidated - payment	Time to pay suppliers Delay Purchase price Desired production Sell price Buying on credit Rate of payment getting paid Bad debt Paying cash	Time to pay suppliers--//→+ Purchase price→-Desired production→-Sell price→+Buying on credit→-Rate of payment→+getting paid→-Bad debt→-Paying cash	**Supplier integration** Excessive delays in paying suppliers lead to bad debt and stockout of medicines. collecting loans for production and having unpaid supplies can lead to collapse of the company which also affects the hospitals.

IS11-11) "It is very important to train staff on government policies ... by way of training you will know how to implement government policies, …how to also understand the relationship between the government, the governmental and non-government agencies who are our donors. Sometimes they brought the equipment to do surgery, do we really need? when you give us drugs that we don't need it becomes a burden to us. So we must have that information of giving us what we need and it will be more valuable to us. Another very important thing is the circular they normally give, early release of circulars on issues that affect the life of some of us … in our field and … this knowledge … implementation is what would make … useful for transmission into services". (132/169)	- train staff - relationship - burden to us - information - circular - early - knowledge … implementation - transmission into services	Capacity Hospital-stakeholder relationship (trust) Shrinking and expiring inventory Information sharing Communication Delay Staff satisfaction Fill rate	Capacity→+ Communication→+ Information sharing→+ Staff satisfaction--//→+Hospital-stakeholder relationship (trust)→- Shrinking and expiring inventory→- Fill rate	**Network integration** Building employee capacity and implementing benefits will increase trust and knowledge gained will be channelled to reduce expiries and improve fill rates.
IS11-12) "for the patient it's counselling at the point of delivering the drug to a patient. If you don't do that, you have not done anything. You must give information on the proper usage to get adherence and outcome. you must also counsel the patient on the storage need of that product. …and ensure they get the right kind of information so that	- counselling - information -delivering - store it well	Information sharing Selling Medicine quality	Information sharing→+Selling→+ Medicine quality	**Customer integration** Giving adequate information to patients prolongs the quality of medicines and increases selling.

they will be able to store it well and complete the dosage.”. (74/119)				
IS11-13) “… we have a hospital formulary which … contains the list of all available essential medicines and it's available in all the prescribing clinics. … they can still check what we have in the hospital. Another way of transmitting information among the clinical department and users is when the drug is available. … in NHIS, we … send it to the emails, they're happy and anywhere they are, they can easily see what we have in the hospital … and that also improve cash sales generations and that also improve the image of those and improved therapeutic outcome of the patient instead of going to open market to buy drugs that you cannot vouch for what is bought”. (117/270)	- hospital formulary - drug is available - easily see what we have in the hospital - cash sales - cannot vouch for	Information sharing Hospital medicine inventory Visibility Cash collected at hospital Substandard medicines exposure	Information sharing→+ Visibility→+ Hospital medicine inventory→+Cash collected at hospital→- Substandard medicines exposure	**Information integration** Providing information and medicines at the hospital reduces exposure to fake drugs in the open markets.
IS11-14) “… I've been trained in this logistic training for one week and it was and eye opener. When I came on board, I met drugs of over 600 million nearing expirations. what we do then is to bring in logistics and called some of the suppliers that is why i said it's good to have a relationship, … come and pick the drugs that will expire and give us far dated medicines. … we also told suppliers to go and detail to the doctors	- logistic training - expirations - relationship - go and detail -tell them about their product	Capacity Shrinking and expiring inventory Hospital-manufacturer relationship (trust) Sales Information sharing	Capacity→+Information sharing→+ Visibility→+ Customer orders→+Sales→- Shrinking and expiring inventory→- Hospital-manufacturer relationship (trust)	**Network integration** Improving staff capacity increase’s ability to fulfil customer orders and trust with partners.

and tell them about their product so that by time they detail their products it will generate prescriptions, it generates visibility … of these medicines". (108/207)	- prescriptions - visibility	Customer orders Visibility		
IS11-15) "The use of digital technology for making medicines available is excellent, i support it 100%. It makes everything easy. It keeps us in line with global best practices. The most important thing is the use of technology to share information to stakeholders and patients. There are a lot of softwares, we use hospipharm and it has been very relevant for us. we use trend analysis we look at the stock level, … on daily basis and i must know the number of patients attended to so and that in a month i will to know the number of patients then stock count of drugs per day, per week. From there we would know our consumption pattern and trend analysis we're using to be able to look at our performance and that's the information we give our stakeholders, our management. if you buy a tin of paracetamol today in NHIS it will finish within three days. we use our consumption to buy drugs… for three months. We already have the performance of the drug. do we have money to buy for three months? if not	- medicines available - share information - global best practices - trend analysis - stock level - number of patients - stock count -performance - finish - money - split the procurement	Medicine inventory Information sharing Benchmarking Data-driven decision making Time period for medicine inventory holdings Customer orders Hospital average order rate Fill rate Stockout Cash at bank Order procurement rate	Customer orders→+ Time period for medicine inventory holdings→+Hospital average order rate→+Order procurement rate→+ Medicine inventory→+ Information sharing→+ Data-driven decision making→+Benchmarking→+ Fill rate→+ Cash at bank→- Stockout	**Network integration** Using data to make decisions promotes best practices and improves fill rate performance.

we buy for one month and then split the procurement into three based on information tracking". (200/235)				
IS11-16) "we have to follow laid down policy and regulations. failure to meet guidelines will cause obstacles or fail to meet expectation of stakeholders. …anticorruption and transparency… i advice people to stick to guidelines and procedures. it helps us to evaluate and improve guidelines for review but when you cut corners, you will not make any influence and performance will suffer". (60/64)	- policy and regulations - obstacles - performance will suffer - expectation - anticorruption and transparency - cut corners	Hospital medicine inventory Stockout Fill rate Cash at bank Corruption	Hospital medicine inventory→-Stockout→-Fill rate→+Cash at bank→-Corruption	**Network integration** Increasing transparency and reducing corruption allows cash to grow and improves fill rate.
IS11-17) "**…**to improve performance, you need to educate patients and make the services available. We have three mandates training, research and services. you research to do services and also train to give services. these services are relevant and useful when beneficiaries are satisfied with the service… we counsel, give health education on risk factors and quality of life even without drugs. Interacting with the patients, recently the government included some drugs on the NHIS list that were not on the list before due to feedback from the service level. The patients now get their medicines,	- services available - satisfied - education - list - service level - affordable price	Medicine inventory Customer satisfaction Information sharing Customer order Fill rate performance Sell price	Customer order→-Sell price→-Medicine inventory→+Information sharing→+Fill rate performance→+ Customer satisfaction	**Customer integration** Reduction in selling prices increases availability and customer satisfaction

government have included paediatric drugs so that the children can get otherwise expensive drug at <u>affordable price</u>". (111/113)				
IS11-18) "…for suppliers, <u>prompt payment</u> will improve their performance. They will give you donation, training, sample of medicines, educate you on clinical training, information and update on trends in treatment and pharmacy training in Africa, … We have just done a training because of our interaction and <u>relationship</u> with the suppliers". (50/64)	- prompt - payment - relationship	Delay Paying suppliers Hospital-supplier relationship (trust)	Paying suppliers--//→+Hospital-supplier relationship (trust)	**Supplier integration** Payment for supplies builds trust among partners.

IS20

ParticipantNumber-Quote number) "... variables in Phrase(s)" (word count in variables/total word count in causal statement)	Phrase(s) from participant quote denoting model variables	Interpreted model variables	Causal link between model variables (→=causal link, --||→=causal link with delay, +/-=positive or negative polarity)	Themes from participant quotes
IS20-01) "we have about four department that works together, the major one is pharmacy department because we are the in charge ... drug expert, but the account are also with because of the payment... the audit are there the store that work with the pharmacy to make sure that the drugs are been stored appropriately if been procured are also there and also the management ...". (64/75)	- works together - drug	Teamwork Medicine inventory	Teamwork→+Medicine inventory	**Internal integration** Working together increase on shelf availability of medicines
IS20-02) ".... the main bottleneck we have is ... during payment after procurement ... it has to undergo a lot of processes from one office to the other, and this this process can take up to in fact I cannot say, more than a month, two, three, four months, depends on what the situation is on ground then. ...to improve this process, I think we can facilitate it as within one week it is possible, because I think I was here when we use to do this process within two weeks latest, but now, I don't know how to explain it, may be if you can see	- payment - procurement - processes - one office to the other - four month - one week - I don't know how to explain it	Paying suppliers Order procurement Process integration Delay Time to pay suppliers Weeks of payables Staff satisfaction	Order procurement→+Paying suppliers--//→-Time to pay suppliers→+Process integration→-Weeks of payables→+Staff satisfaction	**Cash flow integration** There appears to be no transparency as the staff cannot explain what is happening in the system. the departments are working in silos, there's no teamwork. There is finger pointing, the 'us'

the people from account and audit may be in a better position to explain that part, but as a pharmacist, I know we have been trying and we have not changed because we are the one that are here, when I said it is two weeks that will give supplier and they come and collect their money, we are still here today. ... you can see the transformation is not actually with us, others will be able to explain that". (185/195)				versus 'them' syndrome.
IS20-03) "... the major people that work with the patient are we the pharmacist, we are the one that attend the <u>prescriptions</u>, if it is <u>not available,</u> we document so that we will know that this drug is not available when dispensing, ...from the store both active and main store, it should be taken to <u>procurement</u> ... We have the tender system, we have ... the emergency procurement and all others. when we want to buy a lot of drugs ...the tender process. We <u>make a list</u>, we send quotation that is tender for the suppliers... when the <u>price</u> is very ... we go for effective drug with a less cost. in fact, we have a very good relationship with patients as far as I know pharmacy". (125/274)	- prescriptions - not available - procurement - make a list - price	Customer orders Stockout Order procurement Average order rate Purchase price	Customer orders→+ Average order rate→+Order procurement→- Purchase price→- Stockout	**Customer integration**
IS20-04) "... what I mean by counselling unit is anybody that comes	- procurement	Order procurement	Hospital-supplier relationship	**Supplier integration**

from procurement of drug, we attend to them, after filling the prescription then we will now counsel, ... we cannot have a perfect situation on ground but as much as possible we are trying to improve every day. The major problem we have now is supply of drug, ...even if the money is not there, ... I think with good relationship with the supplier, they are ready to supply. But the major problem is the fund which is not directly under the pharmacy department". (94/211)	- counsel - supply - money is not there - good relationship - fund	Information sharing Order fulfilment Weeks of cash at bank Hospital-supplier relationship Cash at bank	(trust)→+Order procurement→+Information sharing→+Order fulfilment→+Weeks of cash at bank→+Cash at bank	
IS20-05) "we still need to improve in our working relationship ... with our supplier ...by paying their funds. ... they will all be happy and rush to this place, because we use to have a lot of suppliers ...that we cannot even deal with all of them, we have to be begging them, that please, you people should go and come back, … but now, a lot of them have gone ... because of payment. We actually working because our drug have to be NAFDAC registered and it is written in our documents for suppliers that we are not taking any drug that is not registered, so if you have any problem with a drug we can call the NAFDAC... (119/214)	- relationship - paying	Hospital-supplier relationship (trust) Paying suppliers	Paying suppliers→+ Hospital-supplier relationship (trust)	**Network integration** Lack of payment for medicines delivered led to loss of suppliers and depletes trust

IS20-06) "with patients.... we have counselling unit, we inform them there, and if there is any patient special information that they want, we also have information centre here, where they can come and contact us... informing them through hardcopies, directly we call them or we a times we write to them ...share hardcopy and a times it is soft copy that we use in informing them...". (65/75)	- inform - they want	Information sharing Customer orders	Information sharing→+Customer orders	**Information integration**
IS20-07) "... we have ...available anaesthetic drugs currently not at re-order level... put the name of the drug, the brand, the balance that we have in the store and the expiring date. ... other drugs are also there, this information is from the store to us procurement....". (45/163)	- available - re-order level - expiring	Medicine inventory Order procurement rate Shrinking and expiring inventory	Order procurement rate→+ Medicine inventory→- Shrinking and expiring inventory	**Supplier integration**
IS20-08) "... by informing them, we improve ... with more regular, maybe on weekly basis we can have ...a bulletin, ... it will help a lot even for the patient, patient can see the bulletin and read, ... information about the drugs, the availability the strength we do that. More I think we need to do it more, let it be more regular". (61/96)	- informing - drugs - let it be more regular	Information sharing Medicine inventory Delay	Medicine inventory--//→+ Information sharing	**Information sharing** Manual methods of sharing information causes delays
IS20-09) " now we... are using the systems [computers] not like ... before	- systems	Digital technology	Digital technology	**Information integration**

that we use hardcopy, but I think it will help in improving the ... procurement supply chain and drug dispensing I think the one we are using now is the computer system but I don't know about any other one". (51/63)	- procurement	Order procurement	→+Order procurement	The staff have limited knowledge on digital technology
IS20-10) "...we use to see a lot of patient here, but at times we will not be able to attend to them because the drugs is like 70% only with the procurement, ... we don't have any problem with the procurement, as much as possible, we know we have good relationship with suppliers, so any time we call them, they will be able to attend, but I have problem with out of stock because of the funds, ... I mean performance pertaining to the fund, I will say 20%, if I am talking about performance according to how I am seeing the patient I will still say 50% because even if you are not really performing well with the patients provided there is adequate information and then advertisement, they know there is pharmacy and they are sure they will get the best here, we still have about 50%- 60%". (148/195)	- procurement - relationship - out of stock - funds - information - about 50%- 60%	Order procurement Hospital-supplier relationship (trust) Stockout Cash at bank Information sharing Fill rate	Hospital-supplier relationship (trust)→+ Order procurement→+ Information sharing→+ Cash at bank→-Stockout→- Fill rate	**Supplier integration** Financial management has the poorest performance with 20%
IS20-11) "... we used to think, maybe ... they can even do better for us,	- inform	Information sharing	Information sharing→+Governme	**Network integration**

especially the account department, maybe they can <u>inform</u> the government fast, ... we need more <u>funding</u>. ... because they are the one in charge of, like me, what I avoid as much as possible even when I was dispensing is to touch money, even if somebody beg me ... I can only look for somebody, I beg follow this man or old woman to where they are paying to go and assist in the mode of paying, but I will never touch your money. ... because I don't know what the problem is, I cannot really blame them, if you sit down with them, they will be able to explain better. But me I used to think maybe they can inform the government parastatal ...so that we will be <u>refund</u> or look for other needs that are in charge of the fund. If we are able to get regular funding in pharmacy, I believe if you cannot go, we cannot be 100% perfect but I believe <u>we can be up to 98%</u>. (185/234)	- funding - refund - we can be up to 98%	Government funding Depositing cash Fill rate	nt funding→+Depositing cash→+Fill rate	Disappoint from lack of funds leads to helplessness

IS21

ParticipantNumber-Quote number) "... variables in Phrase(s)" (word count in variables/total word count in causal statement)	Phrase(s) from participant quote denoting model variables	Interpreted model variables	Causal link between model variables (→=causal link, --‖→=causal link with delay, +/-=positive or negative polarity)	Themes from participant quotes
IS21-01) "we work in as a team, both the accounts departments and the pharmacy to see that there is availability of drugs in pharmacy ...." (24/28)	-team - drugs	Teamwork→+Medicine inventory	Teamwork Medicine inventory	Internal integration
IS21-02) "… things should be done together to improve … all those things there should be availability of funds, that is the most important thing. If there is funds, everything will be available. But if there is no funds, drugs would not be available". (42/52)	- together - funds - not be available	Teamwork Cash at bank Stockout	Teamwork→+Cash at bank→-Stockout	Cash flow integration
IS21-03) "…we have emergency drugs in a situation whereby we don't want too much out of stock… we have what we call emergency drugs committee. Whenever there is no … drugs available, we rush into the committee to make drugs available for the patient. … we work …with the suppliers. The moment we observe that we don't have drugs, they go the procurement write	- drugs - out of stock - procurement - pay	Medicine inventory Stockout Order procurement Paying suppliers	Order procurement→+Medicine inventory→+ Paying suppliers→-Stockout	Supplier integration

immediately, … we rush in… to make things available, we now call the pharmacist…maybe they make the supply. Sometimes they do supply without … paying them… that is how they will bring it before we now pay them". (101/120)				
IS21-04) "To improve the working relationship is by motivating your workers now. There are many ways that you motivate workers to make them work hand in hand with patient. That's like now, if there is incentive, give your workers incentive, you make them work even out of their time. They will work it out for you so that everything will be perfect". (61/64)	- relationship - motivate	Hospital-customer relationship (trust) Staff satisfaction	Staff satisfaction→+ Hospital-customer relationship (trust)	Customers integration
IS21-05) "The suppliers, we have good relationship with the suppliers. So in terms of improvement, I don't think we lack anything that will make us, I don't think that we have problem with them to be make us improve. … state government sometimes offered some drugs, free drugs to us. …we share it to the patient. The patient that is in need of … drugs and we can see that they brought it … we now tell them … we have free drugs, don't buy this, buy that.	- relationship - drugs - in need - don't buy this	Hospital-supplier relationship (trust) Medicine inventory Customer orders Cash collected at hospital	Hospital-supplier relationship (trust)→+Medicine inventory→+Customer orders→+Cash collected at hospital	Network integration Government sometimes donates free medicines to hospitals and the free medicines get mixed up with the DRF leading to

So we go to the pharmacy, we collect the free drugs for them and give it to them." (105/161)				confusion as patients that can afford medicines get refunded and staff divert patients away from depositing cash, leading to excess stock in the revolving fund as medicines already procured are not sold and depleted funds.
IS21-06) "…The information sometimes, … the pharmacist like those our contractors, the representatives, the reps that usually came for, they use to organize seminars now, they use to organize seminars to show this is the drugs they have, …They tell us the good part of it so that you know, to sell the ideas to the doctors and they will now be …prescribing the drugs to the pharmacy to purchase them. We share information of drugs we need, …we do tenders to be sure that these are the drugs that people need, …We go on buying the drugs. You know like being the accountant, so I'm not directly involve in those … information…". (112/155)	- seminars - drugs -sell - people need - buying	Information sharing Medicine inventory Selling Customer orders Order procurement	Information sharing→+ Order procurement→+Medicine inventory→+Selling →+Customer orders	Information Integration Supplier promotion of medicines to prescribers influences prescribing patterns and disrupts the procurement cycle by creating demand uncertainty.

IS21-07) "you know, before it was <u>during meetings</u> that we usually know whether the drugs or during stock taking, that is when we know whether the drugs has <u>expired</u> or how the availability of the <u>drugs</u>, that is during stock taking that is when we get to know what and what we need and what and what we don't have and what and what has been expired. " (66/67)	- expired - drugs - during meetings	Shrinking and expiring inventory Medicine inventory Visibility	Visibility→-Shrinking and expiring inventory→+Medicine inventory	Internal integration Lack of visibility of available and expiring medicines leads to stockout.
IS21-08) "..I will advise them, … to be giving <u>information</u> … … <u>we don't have ways</u> … that of any information, … our own is if there is <u>no drugs</u>, they will come to us, tell us when there is no drugs, how do … we want to do <u>tender,</u> we want to do that, … so that we get information, that is how the …suppliers get information about … after our meeting, we now inform them we don't have this… we are inviting them for tender…". (84/144)	- information - we don't have ways - no drugs - tender	Information sharing Visibility Stockout Order procurement	Information sharing→+Visibility →+ Order procurement→-Stockout	Information integration
IS21-09) "Digital <u>technology</u>, we are not up to that standard now … we don't have … I'm not in that side. I'm not a pharmacist. So I will not know…I don't have any opinion on that because I'm <u>not</u>	- technology - not directly	Digital technology Visibility	Digital technology→+Visibility	Information integration Revolving fund staff in the organisation do

directly with them when they are doing all those things”. (48/68)				not have visibility of the SC.

APPENDIX XII: INTERVIEW ANALYSIS FOR CASE D

Interview Quotation Analysis for Case D

IS08

ParticipantNumber-Quote number) "... variables in Phrase(s)" (word count in variables/total word count in causal statement)	Phrase(s) from participant quote denoting model variables	Interpreted model variables	Causal link between model variables (→=causal link, --||→=causal link with delay, +/-=positive or negative polarity)	Themes from participant quotes
IS08-01) "We have a drug revolving fund committee which comprises of all the departments pharmacy, accounts, audit and procurements, where <u>they sit</u> down and look at submissions made by different companies and the local <u>purchase</u> order is given to the companies to <u>supply</u> drugs." (43/43)	- they sit - purchase - supply	Teamwork Order procurement Order fulfilment	Teamwork →+Order procurement→+Order fulfilment	**Internal integration**
IS08-02) "... there will be a better result if the pharmacist was allowed to do <u>whole necessary parameters</u> because the accounts, the procurement department and the Audit department don't really understand the implications of when we say we need a certain <u>medicine</u> from certain companies. Sometimes we know some of our companies do <u>price adjustment</u> to quote lower for a drug but when asked to supply, they <u>cannot supply</u>. ... the hospital policy is the lowest bidder gets the supply. if	- whole necessary parameters - medicine - price adjustment - cannot supply - procurement process much faster - out of stocks	Order procurement Medicine inventory Cost price Order fulfilment Order procurement rate Stockout	Order procurement→+ Order procurement rate--//→+ Order fulfilment→+Medicine inventory→-Cost price→+Stockout→-Staff satisfaction	**Supplier integration** Some suppliers are exploiting the process to win a bid by quoting the lowest price but when asked to supply, they

pharmacy is allowed to take charge of all those areas, all those preambles to sought out the companies that will deliver irrespective of the cost implication, and the accounts can come in as independent, it will make the procurement process much faster and better, because what we have now is out of stocks, some companies cannot supply because of price change, there are complaints. once the procurement is done, the cycle cannot be repeated three to four months to meet the quarterly resupply". (162/172)	- complaints - four months	Staff satisfaction Delay		claim the price has increased which displeases the staff.
IS08-03) "We have a former procedure, which was changed when this new administration came onboard, the current administration insist that procurement must take charge of everything. Other departments just come in as supporting staff, but procurement is leading the whole thing. So irrespective of what our patients say, in terms of this product works better for them and all that, we have little to say when it comes to procurement meeting, ours is to make provision of what we need and submit to the procurement office. they are the ones that ensure the integrity of the whole procurement process. ... In terms of not meeting up on patients or clients need which we	- procurement - irrespective of what our patients say - we have little to say - provision - end of the quarter - until the next quarter - process	Order procurement Customer satisfaction Staff satisfaction Average order Delay Process integration	Staff satisfaction→+Average order--//→+ Process integration→+ Order procurement→+ Customer satisfaction	**Internal integration** There is frustration on the part of staff as medicines are never enough to serve customer needs.

normally prepare on a quarterly basis. Some of those drugs might finish before the end of the quarter or some might not be supplied. And once the process is over, you don't get any supply until the next quarter. there's little or no much say or interaction between clients, pharmacy and the whole procurement process. ...we may not get the drugs we want ... because of the bottleneck of administration but we still have to let the system run". (191/225)				
IS08-04) "Even though the procurement unit has taken charge, but the user department would play a major role in the procurement process of that particular department because they know what they want, to satisfy the clients. They know what timespan and what quantity of drug will last for a particular time... looking at price templates and determining who is best suitable to supply ... it will go a long way in trying to strike a balance between clients, user department and the procurement process, the procurement can still do the procurement, no problem, but we'll do the integrity of the whole work and submit to them... the store and then pharmacy goes to the store to pick up supplies., ... that way everybody's doing	- procurement - satisfy the clients - quantity of drug - price - supply - patients demand	Order procurement Customer satisfaction Inventory holding period Cost price Order fulfilment Customer order	Customer order→+ Inventory holding period→+ Order procurement→- Cost price→-Order fulfilment→+ Customer satisfaction	**Supplier integration** All the departments must synchronise their processes to improve fill rate

his own role to meet the patients demand". (131/181)				
IS08-05) "... we have a good relationship with our suppliers. we had the former administration, and the current administration has its own rules and regulation but for suppliers as long as you pay them when due ... you give them their money, they are happy and are willing to do business with you anytime you call them to supply they are ready to supply ...". (64/103)	- relationship - pay - supply	Hospital-suppliers relationship (trust) Paying suppliers Order fulfilment	Paying suppliers→+ Hospital-suppliers relationship (trust)→+Order fulfilment	**Supplier integration**
IS08-06) "... over time we are trying to bring awareness to neuropsychiatry diseases, maybe we'll be able to attract NGOs and civil society to partner with us in trying to solve the menace of drug misuse or drug abuse in ... the society, but for now we have very little understanding or relationship with any partners agencies. (55/124)	- over time - partner - drug misuse - relationship	Delay Collaboration Drug abuse Hospital-stakeholder relationship	Hospital-stakeholder relationship--//→+ Collaboration→+ Drug abuse	**Network integration** Reducing drug misuse requires partnerships with all stakeholders
IS08-07) "... whenever anybody requires any information, they use either the pharmacovigilance unit or the counselling unit to give whatever information that person may require. we have a very good unit that handles information". (32/80)	- requires any information - handles information	Information sharing Medicine inventory	Information sharing→+Customer order	**Information integration**
IS08-08) "we have other programmes within every year, two or three times a year. We try to engage, come up with one or two programmes which will	- programmes - create awareness	Information sharing Medicine inventory	Information sharing Medicine inventory	**Network integration**

invite all the stakeholders to get them to create awareness among them, students youths, women groups, organisations, ... and how important this hospital is and try to keep sanity in the country". (58/93)	- keep sanity	Drug abuse	Drug abuse	Prevent drug abuse while maintaining medicine stock
IS08-09) "We have done very well in terms of expiry we try as much as possible not to collect drugs that have less than two years. As since our procurement is on quarterly basis. We know the volume of drugs we consume on quarterly basis, ... its only on few cases that you have expired drugs. we enlighten our patients to always return back these drugs to us. And then we'll see what we can do about it. but we have had one or just minimal case of where patients return drugs that's expired". (93/99)	- expiry - collect drugs - procurement - return back	Shrinking and expiring inventory Order fulfilment Order procurement Reverse logistics	Order procurement→+ Order fulfilment→- Shrinking and expiring inventory→+Reverse logistics	**Customer integration**
IS08-10) "we try to ensure none of our drugs expire and any other information that has to do with drugs, we keep everybody informed. even our suppliers, we give feedback, as the case may be to them. we've had situations where we forced companies to change the colour of medications so as to ... avoid causing confusion among our patients. ... we have a seamless	- expire - information - forced - our patients	Shrinking and expiring inventory Information sharing Hospital-supplier relationship (trust) Customer orders	Hospital-supplier relationship (trust)→+Customer orders→+ Information sharing→- Shrinking and expiring inventory	**Information integration**

interaction between our patients and the suppliers.” (71/126)				
IS08-11) “... we need to get more enlightenment from the hospital itself, not just from the user department... government should really come in, NGOs, other stakeholders should really come in because it's something that affects directly or indirectly.” (37/155)	- enlightenment - government - come in	Information sharing Government funding Hospital-stakeholder Relationship (trust)	Information sharing Government funding Relationship	**Network integration**
IS08-12) “... it is not out of place to use digital technology, but the question is, how well it is, or how literate are our patients to accept use of technology. Most of our patients are rural patients, even the patients from urban area, how many are willing to key into it? It's a welcome idea and needs to be gradually Incorporated. I think it’s a ... long-term plan that should be worked on. but in the interim, I think it cannot serve the cause that it's required to serve”. (89/89)	- digital technology - how well it is, or how literate - long-term - cannot serve	Digital technology Capacity Delay Customer satisfaction	Capacity --//→+ Digital technology→+ Customer satisfaction	**Customer integration**
IS08-13) “we have written about it to the management since it's a government organization, the administrative officers are also there, ...we're still waiting for administrative people to do their job and either approve or disapprove our request. we know that it will help us a lot, we have seen places where technology is being used, and this has	- written - still waiting - bottleneck - technology - effectiveness	Communication Delay Digital technology Fill rate	Communication--//→+Digital technology→+Fill rate	**Network integration**

really improved the effectiveness and efficiency and we believe it will work well for us but for now, ... we still have to wait for the bottleneck to be resolved ...”. (87/113)				
IS08-14) “if I’m to measure medicine availability, I will tell you that the amount of patients needs, ... we're able to meet that is where i will measure the performance index. ...what percentage of patients’ needs are we able to meet. ... we're able to provide on the average 70-80% of the patients’ needs. ... improving the efficacy and efficiency of meeting the demands of clients as the case may be ...”. (71/117)	- patients needs - the demands	Fill rate Customer orders	Customer orders→+ Fill rate	**Internal integration**
IS08-15) “in terms of suppliers, one of the best ways in which we can really meet some of the needs of our clients and suppliers is on signing an MOU with them. there are key drugs that we know, patients who come from rural areas, cannot access these except they come to the urban areas. even though our procurement is quarterly, If we can make sure that these drugs are available all the time, it will reduce the out of stock ...”. (81/120)	- needs of our clients - MOU - drugs - quarterly - out of stock	Customer orders Order procurement Medicine inventory Order procurement rate Stockout	Customer orders→+ Order procurement rate→+Order procurement→+Medicine inventory→-Stockout	**Supplier integration**
IS08-16) “... our patients are very poor, most are from the rural areas, if the government can come in terms of	- subsidy - cost	Government funding Purchase price	Government funding→-Purchase price→-Medicine inventory	**Network integration**

providing a subsidy in which case, it will bring down the cost of medication, patients can easily access this drug and improve compliance with our medications, rather than been exploited at the open markets. Governments can help directly and indirectly by subsidising some drugs costs for the patient will go a long way in really helping us a lot. (78/83)	- drug	Medicine inventory		

MD40

ParticipantNumber-Quote number) "... variables in Phrase(s)" (word count in variables/total word count in causal statement)	Phrase(s) from participant quote denoting model variables	Interpreted model variables	Causal link between model variables (→=causal link, --‖→=causal link with delay, +/-=positive or negative polarity)	Themes from participant quotes
MD40-01) "… the team works as one, by first we have individuals or persons that are in charge of particular products, … such persons know how to source for those products, who to contact. And anytime there are issues, that issue of supplies come comes up, we normally sit together and say, Okay, where do you think we can get this and that and because they are, they are specific as to what they do, a kind of division of labor, it makes it easier. They can easily pinpoint … who to contact, and … we have a database of prices, that guides us as to which of the …companies to call for any particular problem". (114/119)	-team works as one -issue of supplies - division of labor - makes it easier - database of prices - particular problem	Internal integration Distributor customer order Process integration Delivery purchase price order fulfilment	Distributor customer order→+ Process integration→+ Internal integration→- purchase price→- Delivery→+ order fulfilment	**Internal integration** The company achieves higher level of integration with aligned teams and processes which leads to lower cost of medicines and higher fill rate.
MD40-02) "…to have more harmonious relationship than what we have, and we're working towards it. And then again, to improve on our database, because there are some loopholes that needed to be corrected as to how we keep those data". (39/48)	- harmonious relationship - loopholes - keep those data	Distributor-hospital relationship (trust) Visibility Distributor time period for reconciling medicine inventory	Distributor time period for reconciling medicine inventory →- Visibility→+ Distributor-hospital relationship (trust)	**Customer integration** The challenges with data handling and visibility which affects delivery of medicines to hospitals.

MD40-03) "Most of the times because the supplies, we are always regularly in touch with our customers to know what their demands are. And then the moment we have their demands, we sit together with my team to quickly see how we can source them". (44/49)	-supplies - regularly in touch - source them	Distributor customer order Communication Manufacturer customer order	Distributor customer order→+Communication→+Manufacturer customer order	**Information integration** Ease of communication with the hospitals increases the rate of placing orders to manufacturers.
MD40-04) "… improving on our interactions with them, so that we have more information at our disposal than what we have now. That will improve working relationship with them". (28/32)	- interactions - more information - working relationship	Process integration Visibility Distributor-hospital relationship (trust)	Process integration→+Visibility →+Distributor-hospital relationship (trust)	**Customer integration** Providing more process integration will increase trust and visibility of demand.
MD40-05) "…Sharing of information among us, the stakeholders, and then reviewing the previous things that we have done, to see where there are loopholes and correcting them, who will, will improve our working relationships" (33/33)	- Sharing of information - reviewing - working relationships	Information sharing Medicine fill rate Distributor-manufacturer relationship (trust)	Information sharing→+Medicine fill rate→+Distributor-manufacturer relationship (trust)	**Information integration** Medicine fill rate increases with improve information sharing among partners to gain trust.

MD40-06) "… our customers normally give us a list of drugs to quote and normally we respond back by giving them our prices and the type … the products that we're going to give and probably the expiry date in some cases, and we also interact with them to tell them things that are not available right now, for where there are issues that needed to be resolved". (66/79)	- list of drugs - our prices - expiry date - not available right - needed to be resolved	Distributor customer order Sell price Shrinking and expiring inventory Medicine stockout Distributor time period for reconciling medicine inventory	Distributor customer order→+Sell price→+Shrinking and expiring inventory→+Medicine stockout→-Distributor time period for reconciling medicine inventory	**Customer integration** Increasing hospital orders leads to an increase in distributor selling price and stockout at the hospitals.
MD40-07) "… there's a feedback mechanism because those are the upstream …normally wants to hear from us the response of our customers on the ground to their products. … they work based on some of them …for example, had cause to change their packaging, because of the information that we have given back to them as to observations by our customers. … such relationships do exist". (64/73)	- feedback mechanism - response of our customers - change their packaging - relationships	Communication Information sharing Sell price Distributor-manufacturer relationship (trust)	Communication→+Information sharing→-Sell price→-Distributor-manufacturer relationship (trust)	**Information integration** Information sharing between all the partners leads to reduction in prices and builds more trust.
MD40-08) "… the unfortunate scenario here is that because we are in the private sector most critical stakeholders except if you don't normally have to share information with us you know, we businessmen sometimes try to keep so many things secret. … for the regulators, we give them information on drugs availability of some of the drugs in the market and especially	- many things secret - suspect their integrity - privileged information secretly	Transparency Medicines quality Visibility	Visibility→+ Transparency→+ Medicines quality	**Network integration** Sharing information with external stakeholders leads to increase in

about like NAFDAC, some drugs that are in the market that we felt we suspect their integrity, we give them those privileged information secretly”. (84/95)				medicine quality through fake drugs detection.
MD40-09) “while is a good thing because that will make drugs much more available because …it will make it easier to access but unfortunately, … some cautions will have to be taken because the level of digital awareness of our youth is high and even now, some of them are abusing drugs based on the information’s they normally get from the net. So if it is free that aspect needed to be corrected so there’s need for some cautions for us to prevent our wholesome use of drugs …”. (87/97)	- drugs much more available - some cautions - level of digital awareness - abusing drugs	Fill rate Delay Information sharing Drug abuse	Fill rate--//→+Information sharing→+Drug abuse	**Customer integration** Cautions the use of technology as readily available information to customers increases drug abuse among youths.
MD40-10) “We have so many companies now advertise … their products via internet on some platforms ... you can contact them their phone numbers … that's the little I have about digital thing although … I've seen some in … where you can order for drugs online and all that I need to be delivered to your doorstep”. (57/102)	- advertise - the little I have about digital - order - delivered to your doorstep	Selling Capacity Customer order Fill rate	Capacity→+ Selling→+ Customer order→+Fill rate	**Information integration** Improving internal digital capacity will increase sales and hospital fill rate.

MD40-11) "…we segmented some of the drugs and meet people in charge of such each group of the way we classified them. So, we, we have made all the drugs for example, 100% in …in a particular group. So, the ones that are available, we'll try to put them in percentage against the 100%. … if your percentage is lower, then we can now say you are not doing very well in trying to make drugs available within the organization. … we have a target for each person that is handling such groups, that least we should have 70 to 80% of the drugs that are within your class or within your group. So, that way we everybody is on his toes to make sure that drugs are available". (128/138)	- segmented - have a target for each person - percentage against the 100% - least we should have 70 to 80% of the drugs - not doing very well - everybody is on his toes	Key performance indicators Fill rate Medicine stockout Performance-driven	Key performance indicators→+ Performance-driven→+Fill rate→-Medicine stockout	**Internal integration** Use of key performance indicators to drive availability of medicines improves fill rate and reduces stockout.
MD40-12) "While for now, we are not because we've realized that the most stock we have, the better the performance in terms of sales, in terms of revenue generation, and that's why we made this availability of stock a factor a more important factor". (43/43)	-stock - revenue generation - availability of stock	Medicine inventory Financial performance Fill rate	Medicine inventory→+ Fill rate→+Financial performance	**Network integration** Measure of fill rate drives medicine availability and financial performance.
MD40-13) "… sharing information with them, talking with them, listening to them, and also listening to our own customers too has made us … to work on such information's and then try to fill the gaps, in filling the gaps that improves our performances". (43/46)	- sharing information - talking - listening - fill the gaps	Information sharing Communication Fill rate	Information sharing→+Communication→+ Medicine availability→+Fill rate	**Information integration** Fill rate performance improves with communication

	- performances	Medicine availability		and information sharing.

MM39

ParticipantNumber-Quote number) "... variables in Phrase(s)" (word count in variables/total word count in causal statement)	Phrase(s) from participant quote denoting model variables	Interpreted model variables	Causal link between model variables (→=causal link, --‖→=causal link with delay, +/-=positive or negative polarity)	Themes from participant quotes
MM39-01) "We have the sales and marketing department, these people are involved in detailing the products…. when they are new to the hospitals to the pharmacist and doctors for prescription. And these are the same set of people that collect the order, this order is sent to the office. … the store process the order and the logistics department in the office will take them directly to the rep and the rep will now take them [medicines]to the organization that need them." (80/120)	- detailing - collect the order - process the order - take them	Selling Customer order Process integration Delivery	Selling→+ Customer order→+ Process integration→+ Delivery	**Internal integration** Delivery of medicines increases with increasing sales
MM39-02) "…if we have a stock in maybe in Kaduna, so … lead time will reduce to if the order is sent directly to Lagos from the organization, irrespective of whether the rep comes around because the rep goes from one organization to the other. … they can send their order directly to the office or to the manager, then again, if payments is as at when due…, supplying them periodically and on time, then if the organization … can do in such a way that you have a level of the stock, … we don't have to come often to see them to check the order so that they can periodically be	- stock - lead time - goes from one organization to the other - often - send their order	Medicine inventory Delivery Delay Customer order Paying suppliers	Customer order→+Medicine inventory--//→+ Delivery→+ Paying suppliers→+ Fill rate→ - Medicine stockout→	**Internal integration** Stockout reduces when suppliers are paid on time to deliver medicines.

giving us standing orders so that we don't have to run out of stock, it will enhance our operation." (131/208)	- payments is as at when due - level of the stock - out of stock - enhance our operation	Medicine inventory Medicine stockout Fill rate		
MM39-03) "… the rep visits these organizations from time to time to check the stock level and to move around to place order. The same set of people collect the money for the ones that they supplied earlier. …the order is sent to the office where the office will send the products. … the rep which is the interface is the one that moves around to collect money, …moves on to see the procurement to tell them that a particular products level has reduced significantly, and … pursuing the order at the same time, … moves around in the hospitals to ensure that products are prescribed … to ensure that the products … leave the store the same time will be dispensed to the patient." (123/210)	- stock level - place order - collect the money - supplied earlier - send the products - reduced significantly - pursuing the order - leave the store - dispensed	Medicine inventory Customer orders Paying suppliers Account receivable Order fulfilment Medicine stockout Order procurement Selling Fill rate	Medicine inventory →+ Customer orders→+ Selling→+ Account receivable→+ Medicine stockout→+ Order procurement→+ Paying suppliers→+ Order fulfilment→+ Fill rate	**Supplier integration** Paying suppliers helps them to deliver more medicines to the hospitals
MM39-04) "…those of us in the sales and marketing… department that manufacture the drugs, what they do is that from time to time in our office, …we produce a number of drugs.	-time to time - produce	Delay Production	Selling--//→+ Production→+ Suppliers' customer orders	**Supplier integration**

… if what we have in our store has reduced significantly, they start producing and we are not involved in how they source their raw materials, the active pharmaceutical ingredient, we are not directly involved, we are just directly involved in the sales." (74/140)	- source their raw materials - sales	Suppliers' customer orders Selling		When medicines are sold, manufacturers place orders to raw material suppliers to enable production of more inventory to replace sold products.
MM39-05) "… the regulatory bodies have a very good relationship working with us in the sense that the regulate our activities before you manufacture the product must be registered they register your premises for manufacturing, the pharmaceutical society ensure that there is a pharmacist that is on board there is the NAFDAC ensure that there standard procedure there is Good Manufacturing Practice, those ones are in place and we are ISO certified, such that the production …quality is not compromised." (78/220)	- good relationship - regulate our activities - quality is not compromised	Manufacturer-stakeholder relationship (trust) Production Process integration	Manufacturer-stakeholder relationship (trust)→+ Process integration→+ Production	**Network integration** Trust is the basis of process integration and compliance with regulatory bodies to boost production capacity
MM39-06) "… we have standard operating procedures for our products that we detail, we give ... information to most especially the doctors that will prescribe it. And we will ensure … they get back to us, especially on adverse drugs. And we cascade this directly back to the office, we take them seriously. And the information about our products are well	- standard operating procedures - information - they get back to us - made available	Process integration Information sharing Information integration	Process integration →+ Information sharing→+ Information integration→+ Visibility	**Information integration** Sharing information and receiving feedbacks from hospital

spelt out…don't have anything to hide about adverse effects, adverse reaction… they are given to the patient, given to the doctors given to the end users, …these too are made available to the regulatory authorities." (95/166)	- don't have anything to hide	Visibility		staff puts more pressure on the need to integrate information sharing with stakeholders
MM39-07) "… information sharing is such that's very important …, when you share … the correct information. If there not properly shared, the could result in to mistrust, if a particular product is supposed to have an adverse effect, and it's not properly written out, and the patient should come down with it, it can embarrass the doctor, it can embarrass the patient, and it can cause the a …bad feedback mechanism for the company. …we don't hide … things." (78/118)	- information sharing - mistrust -bad feedback mechanism - hide	Information sharing Manufacturer-stakeholder relationship (trust) Order procurement rate Visibility	Visibility→+ Information sharing→+ Manufacturer-stakeholder relationship (trust)→+ Order procurement rate	**Information integration** Visibility of operations improves information sharing about medicines and trust in the system. Procurement increases with trust.
MM39-08) "… there are some … government policies that may not make the drugs to be available as at when due. … when you import drugs, and you are to repatriate the money, the exchange rate is such that when you are the repatriate the money, … product that has been sold for a particular price and you have gain, and you are repatriating this money and dollar has increased, so it will affect the profitability of the of the company. we ensure that all our SKU's, our stock keeping units are always	- not make the drugs to be available - stockout - when due - a period - import drugs - repatriate the money	Stockout Delay Order procurement Accounts payable	Accounts payable--//→+ Medicine stockout→+Purchase price→+Mark up→- Medicine inventory→+ Order procurement rate	**Cash flow integration** Fluctuating exchange rate between dollar and naira makes it difficult to pay for import medicines and

<u>available</u> at any given time. …we ensure that those products …have <u>reorder level</u>. There could be … a stockout for <u>a period</u> of time, we ensure that we don't have stock out often." (124/190)	- price - profitability - always available - reorder level	Purchase price Mark up Medicine inventory Order procurement rate		raw materials leading to losses on the part of manufacturers from government exchange rate policy.
MM39-09) "… if the <u>financial</u> …performance in terms of the products are being available, as at <u>when due</u> determines our <u>profitability</u>… we ensure that the product are <u>always available</u> all the time so that we don't have <u>stockout</u> and this determines our profitability as well." (43/48)	- performance - when due - profitability - always available - stockout	Paying suppliers Delay Mark up Medicine inventory Medicine stockout	Paying suppliers--//→+ Mark up→+ Medicine inventory→- Medicine stockout	**Cash flow integration** When manufacturers pay suppliers on time, they but more medicines and stockout reduces.
MM39-10) "Yes, it has actually enhance … our operations …, before the advent of the deployment of <u>digital or social media</u>, we send … requests by DHL to Lagos but now, you can snap and send immediately and it will be processed so <u>delay</u> time has reduced significantly then making calls, being able to send reports from wherever you are, and it's received anywhere in the world. It has <u>enhanced our activity</u>." (71/78)	- digital or social media - delay - enhanced our activity	Information sharing Delay Order fulfilment	Information sharing--//→+ Order fulfilment	**Information integration** Use of digital technology makes communicatio n faster and increases medicines Order fulfilment.

APPENDIX XIII: INTERVIEW ANALYSIS FOR CASE E

Interview Quotation Analysis for Case E

IS23

ParticipantNumber-Quote number) "... variables in Phrase(s)" (word count in variables/total word count in causal statement)	Phrase(s) from participant quote denoting model variables	Interpreted model variables	Causal link between model variables (→=causal link, --||→=causal link with delay, +/-=positive or negative polarity)	Themes from participant quotes
IS23-01) "… the store demand… out of stock list, the pharmacy process the out of stock… send it for approval, when it is approved… maybe supplied … the process for that is how they process they payment from the account… we sell medicines, and the collection is done by the account. … it is based on the receipts with the confirmation of the price that we costed. Then we supply the drugs to the patient". (73/110)	- out of stock - supplied - payment - price	Stockout Medicine inventory Paying suppliers Sell price	Stockout→-Medicine inventory→+Paying suppliers→-Sell price	**Internal integration** Stockout leads to procurement of medicines from suppliers.

IS23-02) "If there is <u>internet connectivity</u>, it is easier, you don't have to stand up from your workspace and go to the account to process the <u>payment</u>. And the store people don't need to write <u>out of stock</u> to us with the hard copy…. from our computer, we'll be able to assess out of stock and then process for the <u>new</u>. …if there is consistent computer systems, <u>communication</u>, internet connection and availability". (71/72)	-internet connectivity - payment - out of stock - new - communication	Technology integration Paying cash Stockout Medicine inventory Information sharing	Technology integration→+Paying cash→+ Medicine inventory→+ Information sharing→-Stockout	**Cash flow integration** Manual process delays procurement and payment leading to stockout.
IS23-03) "…from the pharmacy we request <u>stock</u> from the store that we want to serve to the patients… the store issue the drugs to us and then subsequently <u>dispensed</u> to the patients. …people have come in contact with the patient is the pharmacy and account because we <u>cost</u>	- stock - dispensed - cost - pay	Medicine inventory Selling Sell price	Medicine inventory→+Selling →-Sell price→-Cash collected at hospital→+Network performance→-Wait time	**Network integration** Even though there is some delay, the staff can sell

the drugs and then the patient goes to the cashier to <u>pay</u>. we have effective <u>network,</u> the patient does not <u>stay longer</u>". (69/136)	- network - stay longer	Cash collected at hospital Network performance Wait time		medicines to patients. Technology improves performance
IS23-04) "…when the <u>out of stock</u> is issued to us from the store, we <u>process</u> for the stock that we need after processing to send it for approval, when the approval is given, we issue … the <u>local purchase order</u> is issued to the suppliers, we give them a minimum of two weeks to make the <u>medicine available</u> to the pharmacy". (60/75)	- out of stock - process - local purchase order - medicine available	Stockout Process integration Order procurement Order fulfilment	Stockout→+Process integration→+Order procurement→+Order fulfilment	**Internal integration** Aligning processes allows delivery of medicines to hospitals
IS23-05) "if you have computer systems and things are working the way it's <u>supposed to work</u>, from the doctors, the prescriptions is supposed to be online, … you see what drug is <u>prescribed</u> for the	- supposed to work - prescribed - money	Staff satisfaction Customer order	Digital technology →+ Process integration →- Shrinking and expiring inventory→ --//→+Staff	**Information integration** Process integration using

patient. And then you tell the patient how much the money to pay, the patient pays the money and collect the drugs. But most of the time because we don't have that quality system, it delays and some patients when they are given hard copy prescriptions, they don't go to the pharmacy, they buy their drugs in the town and to get the drugs become very difficult for them. it can be improved by computers and internet". (111/125)	- quality system - delays - buy their drugs in the town - difficult - computers and internet	Cash collected at hospital Process integration Delay Shrinking and expiring inventory Stockout Digital technology	satisfaction→+Customer order→+ Cash collected at hospital→- Stockout	technology reduces expiries and increases cash flows. The risk of patients seeking medicines from open markets also decreases.
IS23-06) "…if you we have …pre-qualified suppliers, we don't need to go through this local purchase order. As soon as the drug finishes, you just call the person please supply us and they supply… as they are supplying, we are selling and we are paying them to reduce the out of stock and time for the process	- pre-qualified suppliers - drug finishes - supplying - selling	Supplier integration Stockout Order fulfilment Selling	Supplier integration→- Time to average orders→- Order fulfilment→- Stockout→- Selling →+ Paying suppliers	**Supplier integration** Strategic alliance with suppliers reduces procurement

of purchasing, … we have to sit down and process. … take it for quotation by the supplier, … we gave them one week to bring the quotation, now we're trying to analyse it and give them LPO, it takes time. when we have pre-qualified suppliers, we just call them to bring drugs and we pay them". (113/139)	- paying - time for the process of purchasing - it takes time	Paying suppliers Time to average orders Delay		processing time and stockout.
IS23-07) "we have what is called the drug revolving fund which is a seed money given to hospitals to provide drugs. For the past 20 years government has not provided any money to DRF. we have been using the seed money we had then to revolve, and it has generated a lot of money because at the end of the year, sometimes we have more than 50 million…. we use it for drug revolving fund. If government can fund the hospitals especially the drug aspect, it will really improve because it's not every	- seed money - drugs - not provided any money - revolve - generated a lot of money - end of the year -- not every drug	Government funding Medicine inventory Allocated funding Selling Cash at bank Delay Stockout	Government funding→+Medicine inventory→+ Selling→+ Cash at bank--//→- Allocated funding→+ Stockout	**Cash flow integration** Allowing the funds to grow improves medicine availability but stockout increases without continuous funding.

drug that we have due to paucity of fund”. (101/116)				
IS23-08) “…The information we share with the patients on the issue of medicine mostly is what we call pharmaceutical care. When the patient is being prescribed with particular drugs and the drug is costed and the patient goes to pay. we sit the patient down and tell him the likely side effects, … if you don't inform the patient, how he will feel when … uses the drugs, he may not continue using the drugs. So we try to make sure that we give the patient as much information about drugs they're using as possible. Sharing information with the supplier, most of the time, we want them to supply drugs with specifications, … we use brand to ensure quality”. (118/208)	- information - medicine - costed - pay - specifications - quality	Information sharing Medicine inventory Sell price Cash collected at hospital Desired delivery Medicine quality	Information sharing→+ Medicine quality→+ Desired delivery→+Medicine inventory→-Sell price→-Cash collected at hospital	**Information integration** Sharing information with suppliers increase quality of medicines and increases cash at bank.

IS23-09) "… hospital formulary is a list of drugs that is … the management that could be used in that particular hospital. Drugs are procured and prescribed within the formulary. it helps the government know the type of drugs we use". (40/53).	- formulary - procured - type of drugs	Information sharing Order procurement Medicine inventory	Information sharing→+Order procurement→+Medicine inventory	**Information integration** Sharing information increases medicines inventory.
IS23-10) "We inform store people of certain levels of stock that we have reached which leads to out of stock because of lead time. If for example, you have a particular drug that is moving fast. when 200 bottles are left in the store, they have to alert us to procure the drugs which is supplied in not in less than two to three weeks. … we always have stock taking every month and check expiry dates, we have a policy that we	- inform - levels of stock - out of stock - moving fast - procure - supplied	Information sharing Medicine inventory Stockout Customer orders Order procurement Order fulfilment	Medicine inventory→+ Information sharing→+ Order procurement→+ Customer orders→+ Order fulfilment→- Shrinking and expiring inventory→+Stockout	**Internal integration** Information sharing reduces expiries as fill rate increases.

don't collect any drug that is less than one year from expiration…”. (94/123)	- expiration	Shrinking and expiring inventory		
IS23-11) “The supplier is given conditions when they are making supplies. they should not supply anything that is less than 1 year. … is the duty of the pharmacy to share information that is related to any drugs, and to do that we need more hands in the pharmacy department. If you really want to practice pharmaceutical care, every pharmacist has to get an office to educate the patients on the drugs, these days because of the internet, most patients might even know about drugs than the pharmacist. So, at least as a pharmacist you need to be up to date....”. (100/161)	- conditions - less than 1 year - information -more hands - up to date - drugs - internet	Desired medicine in transit Shrinking and expiring inventory Information sharing Capacity Medicine inventory	Desired medicine in transit→+ Medicine inventory→+Capacity → +Technology integration→+Information sharing→- Shrinking and expiring inventory	**Information integration** Improving capacity of staff reduces shrinkage through technology integration

IS23-12) "Information sharing with suppliers is very important. Some adverse drug reactions may not be known by the supplier as businessperson, such as adverse drug reactions. when patients inform pharmacist about adverse drug reaction, we inform the supplier of the drug. …". (40/109)	-Information sharing - drug	Information sharing Medicine inventory	Information sharing→+Medicine inventory	**Information integration** Sharing information increases medicine availability
IS23-13) "if we have a system that works and we have pre-qualified suppliers, once the drug is about finishing, we just call and the supplier brings the drugs to avoid out of stock. …where you don't have the money that you want. So, most of the time we buy as the need arises not the quantity we need. … the supplier should be able to make available those quantities for us, but because of the available money, we just	- pre-qualified - out of stock - money - quantity we need - prices - revenue generation	Supplier integration Stockout Cash at bank Desired delivery Purchase price Mark up	Supplier integration→+ Desired delivery→- Purchase price→- Mark up→+ Cash at bank→-Stockout	**Supplier integration** Sending out multiple orders makes procurement expensive and purchase price increases.

bought some supplies about a month ago, and some of those drugs are finished and now we're processing another order. because of the paucity of fund we don't keep large quantities. In Nigeria now, nothing is constant, prices keep changing and that affects the patients and affect the revenue generation…". (128/183)				
IS23-14) "we have … annual budget, … we also have projects how much we expect to generate in a year. Digital technology is a critical area that almost everywhere and what everybody is expected to have because it makes things easier, as you can see the quantity of medicines used and what is available. We have this EMR, Electronic Medical Record which is internet enabled system, the doctor prescribe drugs and the patient comes here we log in to retrieve the information of the patient and drugs	- annual budget - how much - medicines used - available - Electric power	Desired delivery Cash at bank Selling Medicine inventory Infrastructure	Infrastructure→+Desired delivery→+Medicine inventory→+ Selling→+ Cash at bank	**Internal integration** Electronic prescriptions and use of technology is hampered by infrastructure deficit.

prescribed. Electric power is a problem as it is not always available, we have solar power but …is not too effective". (107/131)				
IS23-15) "… Before COVID-19, we purchase drugs of about 70 million in a year. Despite that, we still have out of stock which is … minimised through a policy where the management also help us in approving the purchases on time. Prompt approval for purchase also help us. However, if we talk about the availability of the drugs to the patients. i will say at least 60% of medicines is always available for the patients. we measure performance based on out of stock. for … the supplier, sometimes you have the drugs now, before the purchase order is given to the … supplier, the drug is no longer available". (107/118)	-purchase - out of stock -60% of medicines - drug is no longer available	Order procurement Stockout Fill rate Medicine on order correction	Order procurement→+ Medicine on order correction→+Stockout→-Fill rate	**Supplier integration** Suppliers get stocked out of some medicines and adjustments have to be made which also reduces fill rate.

IS23-16) "…. the account department, the pharmacy department and the store department can only help the patients … not to allow the drug to completely finish. Once the drugs reach reorder level, they inform us. … we make sure that the suppliers supply the drugs, and the account people should make sure they pay the supplier to encourage them for continuation of the supply. … one thing is for a supplier to make supply, … if he's not being paid, he will not supply when given another supply". (87/127)	- finish - inform - supply - pay - continuation of the supply	Stockout Information sharing Order procurement Paying suppliers Credit score	Stockout→+Information sharing→+Order procurement→+Paying suppliers→+Credit score	**Supplier integration** Paying suppliers improves hospital credit score leading to continuous replenishment and flow of products.
IS23-17) "to set targets through the budget… we make sure if the government supports us, we will be able to make it, because of this TSA we have now, whatever percentage the DRF makes the government takes 35%. So, they make sure their eyes are there and	- government supports - takes 35%	Government funding Mark up	Mark up→-Government funding	**Network integration**

based on the budget that will always put in their interest…. the stakeholders like the government, things are not working. …". (66/96)				

IS24

ParticipantNumber-Quote number) "... variables in Phrase(s)" (word count in variables/total word count in causal statement)	Phrase(s) from participant quote denoting model variables	Interpreted model variables	Causal link between model variables (→=causal link, --||→=causal link with delay, +/-=positive or negative polarity)	Themes from participant quotes
IS24-01) "… store generates the needs, to the procurement…for replenishments … we now request for quotation from various suppliers to bring quotation … based on the … Nigeria procurement act 2007, because anything… out of it, we have violated the procurement act, and which is a fraud. They will look at it, analyze both technical and financial, we will … the one that is responsive, … responsive doesn't mean that it must be a lower price order. … criteria we use in measuring … the supplier that is responsive, … we now send the document to the chief executive which is the chief procurement officer based on the law, will now give approval. …	- needs - replenishments - quotation - to supply - items - payments - out of stock	Customer orders Order procurement Purchase price Order fulfilment Medicine inventory Paying suppliers Stockouts	Customer orders→+Order procurement→-Purchase price→+Order fulfilment→+Medicine inventory→+Paying suppliers→-Stockouts	**Internal integration**

we now tell the supplier to supply the items, … the store will now raise … goods received note … all the necessary documents… job completion certificate…we will now send it to accounts…for payments, …we don't normally have what we call out of stock ...". (158/736)				
IS24-02) "… we are on the process, … based on manual, so now, the world is a global village, based on the… internet…what should be done … is to automate the system, … once you make a requisition, they is no need to be, taking physical hard copy, up and down, you just transmit it to the procurement, through an automated system…the procurement officer will work on his own, and transmit it to the necessary person, even the supplier, we develop a system that we can link our supplier, … it will save time, and to shorten, the lead time we are talking about, and it will shorten the patient waiting, some patient may be waiting for all this drugs, what am talking about, but, using this system, using automated system …will improve the availability of the drugs ...". (138/212)	- process - automate - procurement - save time - shorten, the lead time - patient waiting - drugs - availability	Process integration Digital technology Order procurement Time delay Wait time Medicine inventory Fill rate	Digital technology→+ Process integration→+Order procurement→+ Medicine inventory--//s→-Wait time →-Fill rate	**Information integration**

IS24-03) "... we are working round to satisfy our patients. …we are working together… when the needs arises … make requisition, where procurement will process it, will send it to the necessary people, supplier make it available and the pharmacist that directly link to the patient have the drugs to dispense to the patient,…the accounts make available the money that will …use to procure the items… procurement cycle … some supplier will come… will come with an incentive, discount… may be the former drug we are using is more expensive, I will give you a discount… some item that are already, in emergency… because of short life, you cannot buy it in bulk and keep… they are some items you cannot keep… temperature …because we have established a good relationship with the supplier … make it available by this morning, …I will be waiting for you in the hospital to deliver this items, … we give them short notice, because of the relationship we have established, overtime, … in term of payment, to the supplier, they … get their pay, as at when due, we don't delay, … many of the supplier, like to … work with us...". (256/714)	- satisfy our patients - together - needs arises - process it - available - money - discount - relationship - overtime - pay	Customer satisfaction Teamwork Customer orders Order procurement Order fulfilment Cash at bank Purchase price Hospital-supplier relationship (trust) Delay Paying suppliers	Teamwork→+Customer orders--//→+ Hospital-supplier relationship (trust)→+Order procurement→-Purchase price→-Order fulfilment→+Cash at bank→+ Paying suppliers→+ Customer satisfaction	**Customer integration**

IS24-04) "…when you are working with manual … it … delays, … we are trying to do, and … electronic medical record, we shorten the patient waiting time, … if we work at the system, … from the medical record, up to the seeing doctor… we have shorten the waiting time now… everything is going electronically, medical record, instead of you to be writing, you just take your data, … to go and see doctor … there is no need for writing prescription, go and collect your drugs in the pharmacy, … you make your payment, … to accounts… either you use your POS or you use your cash…" (134/246)	- delays - shorten the patient waiting time - electronic medical record - waiting time - prescription - collect your drugs - cash	Delay Digital technology Waiting time Customer order Selling Cash collected at hospital	Digital technology→+ Customer order→+ Selling→+ Cash collected at hospital--//→-Waiting time	**Information integration** Integrating point of sale technology increases cash collection speed
IS24-05) "… we have some supplier through e-procurement, you know, in government setting, e-procurement …, they are gradually introducing … you cannot compare government setting with private setting, government setting has to do with law, … in government setting, you cannot just implement it … has to be backed by law, …for this e-procurement, … I know we will get there…". (60/177)	- supplier - e-procurement	Information sharing Process integration	Process integration→+ Information sharing	**Information integration**
IS24-06) "… we have a good relationship with … all those partners, … every month we give them the stock balance. …we do it manually, but through electrical, that there is no need	- relationship - stock balance	Hospital-stakeholder relationship Medicine inventory	Hospital-stakeholder relationship--//→+ Government funding→+Information sharing→+Medicine	**Network integration**

for the donor to come here, we … send your report… the <u>e-mail or through any other platform</u> that is established, they will see it, audit report … financial account … the <u>money</u> they donate. … will be transmitted electronically… the system will be improved. …all the money <u>government now make available</u> … this is the money we <u>spend</u>, through the audit process. … we improve the relationship, because we give returns to government… we invite some civil societies…Bid opening, we invite the civil society to witness it… for procurement of medicine, … so that they will see that we are transparent …”. (135/519)	- do it manually - e-mail or through any other platform - money - government now make available - spend	Delay Information sharing Cash at bank Government funding Order procurement	inventory→+ Order procurement→+ Cash at bank	
IS24-07) “… we make <u>the list</u>… send it to the… pharmacist… they will … compile the list…send it to the… doctors, so on the platform, immediately doctors want to prescribe, they will now see, that, this is the drugs that is <u>available</u>, …give <u>information</u>… to the patient that, …about the availability of drugs... with the suppliers, … we have generics and non-generics, … procurement act 2007 prohibits … brand, … only generic, so when to share information to the supplier … you describe the <u>component of the drugs</u>…	- the list - available - information - component of the drugs - government - money - our needs	Average order Medicine inventory Information sharing Desired delivery Government funding Cash at bank Inventory holding	Inventory holding→+Average order→+ Desired delivery→+ Information sharing→+ Government funding →+Medicine inventory→+Cash at bank	**Network integration**

we share information, especially our donor, … based on that, they will make it available, … … based on our budget …need from <u>government</u>, because they are our financier, they are the ones that provide <u>money</u> for us to buy… through budget… we inform the government, on <u>our needs</u> …". (135/505)				
IS24-08) "… information sharing…during the COVID19… lockdown, they have reduced the <u>number of patients</u> seen, because to reduce the crowd … we have devised a means that patients will be informed … <u>through SMS</u> …, we discover that the lead time we give to supplier is much and if we didn't <u>shorten the lead</u> time it will affect, <u>availability of drugs</u>, which will <u>affect our patient</u>, … the end user… through electronic system, we communicate to the supplier ... we communicate to them …via SMS, via phone call, via email, other electrical means of communication". (93/276)	- information sharing - number of patients - through SMS - shorten the lead - availability of drugs - affect our patient	Information sharing Customer orders Digital technology Delay Medicine inventory Customer satisfaction	Information sharing--//→+ Digital technology→+Customer orders→+Medicine inventory→+Customer satisfaction	**Customer integration**
IS24-09) "... we are getting there one day, … this is the global <u>best practice</u>, … we work with government, … you just don't implement what government has not said but government are making sure, … instead of <u>carrying files up and down</u>, for patient, for staff, <u>e-</u>	- best practice - carrying files up and down - e-governance - procurement cycle	Fill rate Delay Digital technology Order procurement	Digital technology→+ Order procurement--//→+ Fill rate	**Supplier integration**

governance, … is … evolving …, in future time, everybody will adopt it, inventory management system, real-time system… the procurement cycle of a team will now be through e-procurement, not manual, anymore, we will get there one day”. (85/144)				
IS24-10) "…we have … electronic medical records… but internal, … we design it in, such a way that the drugs that is available in the store … will reflect to the pharmacy, … they will see in the dashboard … when the item is expired…we need ... to improve on this existing one … internet enabled...”. (55/238)	- electronic medical records - drugs - dashboard - expired	Digital technology Medicine inventory Visibility Shrinking and expiring inventory	Digital technology→+ Visibility→+Medicine inventory→-Shrinking and expiring inventory	**Information integration**
IS24-11) “…to measure the performance… medicine available to the organization. … is eighty percent. … we know that they are some medicines that… are slow moving medicine that is not often, when we bought it is expensive and may be it will expire on us, in other to cut cost, we don’t buy such those items plenty, … the relationship we are having is that, at least, we make drugs available… the number of out of stock is very minimal, we don’t have out of stock, … the bin card has reached the stock level… stock level we use to measure our performance”. (115/395)	- medicine - eighty percent - expire - cost - relationship - out of stock - stock level	Medicine inventory Fill rate Shrinking and expiring inventory Purchase price Hospital-supplier relationship (trust) Stockout Inventory holding	Hospital-supplier relationship (trust)→+ Medicine inventory→+ Inventory holding→- Purchase price→+ Shrinking and expiring inventory→+Fill rate →-Stockout	**Supplier integration**

IS24-12) "… we have to go electronically, … to know the real… needs, manually is taking time, but electronically will give … clear picture, of what you need… to increase our performance". (31/82)	- electronically - performance	Digital technology Fill rate	Digital technology→+Fill rate	**Information integration**

IS25

ParticipantNumber-Quote number) "... variables in Phrase(s)" (word count in variables/total word count in causal statement)	Phrase(s) from participant quote denoting model variables	Interpreted model variables	Causal link between model variables (→=causal link, --||→=causal link with delay, +/-=positive or negative polarity)	Themes from participant quotes
IS25-01) "… the departments …work together to make drugs available. … procurement are the people that procure drugs, but the pharmacy, they are the people that know the right drugs to get that the people that the patient will need. … we now make a procure list to the procurement department, then the procurement department, they are concerned with … going out to the market or to the warehouses and to the suppliers and checking the expiring dates and sometimes, may be the quantity and may be the prices, … the account department … has to do with money, the payment, …". (101/257)	- procure drugs - right drugs - patient will need - the expiring dates - prices - payment	Order procurement Desired delivery Average order Shrinking and expiring inventory Purchase price Paying suppliers	Average order→+ Desired delivery→+ Order procurement→+ Purchase price→+Paying suppliers→-Shrinking and expiring inventory	**Internal integration**

IS25-02) "… we all need each other, nobody works in isolation, it's a team … that involves the four departments, … before the drugs get finished, …procurement people see the drugs, because they are some drugs that move faster than the others. … we need these drugs, …drugs will finish… it's a very long process. … the procurement will now make a list of the drugs that will be needed, …the account people will now make the payment, … The store people should be able to make a list of the drugs that are finishing, not allowing it to finish, before telling the procurement, then the procurement should … not to allow a very long time before telling the pharmacy people, … the quotation… will now delay again … even when they make the quotation, their money doesn't come immediately, … because whenever this four departments are doing, it affects the patient...". (151/410)	- team - get finished - move faster - drugs - long process - list - payment - very long time - delay again - affects the patient	Teamwork Stockout Average order rate Medicine inventory Process integration Order procurement Paying suppliers Delay	Teamwork→+ Process integration→+ Average order rate→+ Order procurement→+ Paying suppliers→- Stockout→- Customer satisfaction	**Internal integration**
IS25-03) "… it's a committee, they are saddled with the task of providing the drugs at the right time, in the sense that, when it comes to bulk purchase, then this committee will be able to sit down, discuss, before, the drugs get finished, and how things will be done, because	- drugs - right time - bulk purchase - drugs get finished	Medicine inventory Delay Order procurement Stockout	Order procurement→+ Medicine inventory--//→- Stockout→-Fill rate	**Supplier integration**

… they will put heads together to make sure that the drugs is available at the right time, for the patient". (71/143)	- drugs is available	Fill rate		
IS25-04) "… the right drugs… teamwork with these four departments with the suppliers… we have different brands, they will need to detail their drugs … we can have … the same drugs with two different prices, from two different suppliers. One might be having 5ml, one might be having 10ml, the one having 10 ml, we will consider the one that can last the person for a month and at what price. …with suppliers when it comes to payment, for their money, for the drugs they've already supplied, …will check the expiring date …" (93/380)	- drugs - brands - detail - price - money - expiring	Medicine inventory Desired delivery Information sharing Purchase price Cash at bank Shrinking and expiring inventory	Medicine inventory→+ Information sharing→+Desired delivery→-Purchase price→-Cash at bank→-Shrinking and expiring inventory	**Cash flow integration**
IS25-05) "these four departments…we need help from each other, for us to give our best to the patient, …when the drugs are reducing, so that they will be able to intimate the pharmacy …would now make a list of drugs for drugs purchase, … sometimes the patient will come, because one department did not do what they are supposed to do, they will now say that we don't have the drug, … most of the patients will want to get the drugs from the hospital, they don't want to go to the open market,	- each other - best to the patient - drugs are reducing - make a list - purchase - quality - waiting time	Teamwork Customer satisfaction Stockout Average order Order procurement Medicine quality Waiting time	Teamwork →+ Average order→+Order procurement →+Medicine quality →- Sell price--//→- Paying suppliers→- Waiting time→+ Stockout→-Customer satisfaction	**Network integration**

they always feel that the one they get from the hospital, the quality is assured. …waiting time …patient… its interwoven… it will take a long time for the accounts people to make payment to suppliers, and most of the suppliers, they don't like being owed. …when you don't pay them on time, they will now add that money, because you are not paying them on time, then the price of the drugs will increase and definitely it will affect the patient. …all these things affect the output of what you get at the tail end… in some organization, … for this government hospital, they pay us from Abuja. They now said some hospitals should pay, some of them might not be able to pay because, the output that is coming cannot be able to pay their staff, because they are not putting their best, they are not taking it personal, as if it's their own". (248/623)	- take a longtime - don't pay them on time - payment - price	Time delay Paying suppliers Sell price		
IS25-06) "… knowledge is power, you can only give what you have, so the information, it comes as drug information and sometimes, you go extra mile, because of the empathy you have, for the patient, it might not be your field, but you go extra mile, putting that patient in your shoes, you	- information - the best - product	Information sharing Customer satisfaction Medicine inventory	Medicine inventory→+ Information sharing→+ Customer satisfaction	**Information integration**

give him the best, … share information concerning their product, and other brands. …" (67/480)				
IS25-07) "...we do daily stocktaking, ...we know the ones we sold for the day, and from there, we also do monthly stocktaking... from those calculations they will be able to know the drugs that have been used, the ones that are moving fast, and the ones that are not moving fast, so we have daily stock taking...". (56/126)	- stock taking - sold - been used	Inventory holdings Selling Customer orders	Inventory holdings→+ Customer order→+Selling	**Internal integration**
IS25-08) "…things that need to improve… like putting it on the system, … so that…other departments… from the clinic … can send information to, me in the pharmacy… we are able to retrieve that information. … the systems, the patients phone number, sometimes they are on the system, we can contact them … we also have a … book that will record patients, like some of… the system … we are already doing…". (72/142)	- system - information	Digital technology Information sharing	Digital technology→+Information sharing	**Information integration**
IS25-09) "… digital technology… everything is going digital … it makes it faster, … accurate, less time. … electronic media medical record. The, EMR has different sections, pharmacy is different from procurement, which is different from store, when you open the EMR for store, you should be able to	- digital technology - quantity - reducing - prescribed	Digital technology Medicine inventory Stockout Customer orders	Digital technology→+Medicine inventory→+ Order fulfilment→+Customer orders→+ Selling→- Stockout	**Customer integration**

find the different eye drop we have, the quantity at which they are reducing, … the drugs they have prescribed for them, …you see the different drugs, then you see the quantity, the ones they have supplied us, the expiring date, then how they are being issued…". (95/300)	- supplied - being issued	Order fulfilment Selling		
IS25-10) "… to measure your performance, we use stock level, to measure our performance,… then another parameter that we use to measure performance is the number of out of stock, if a prescription comes, they was … a time that most of the drugs, we don't have, so if a prescription comes, and they are about 6 drugs and we have only 1, it means that the performance is low… so we wouldn't want it to go down to that level". (80/187)	- stock level - out of stock - prescription - performance is low	Inventory holding Stockout Customer orders Fill rate	Inventory holding→-Stockout→-Customer orders→+Fill rate	**Customer integration**
IS25-11) "…we have to work together, …there needs to be teamwork, all these departments, they have to be proactive, because we all need each other. …one department is not proactive, it affects the other, so we all need to sit-up, do the right thing at the right time, so it will not affect the patient….the suppliers, because when they are not paid at the right time, they are not, they are not happy, so when, even this	- teamwork - right thing at the right time - patient - they are not happy - will not be happy - tie their money down	Teamwork Fill rate Customer satisfaction Supplier satisfaction Bad debt	Teamwork→+Fill rate→+Customer satisfaction--//→+ Sell price→+ Supplier satisfaction→-Bad debt	**Customer integration** The patients pay for the delay in paying suppliers by the hike in prices.

framework you are talking about, engaging them, they will not be happy, because they know you will tie their money down, you are not going to pay them on time, so they will not be able, they will not want to supply, and when they want to supply, they will put extra money, and the drugs will be higher, for the patient, they will now be complaining, and even …they are buying the drugs, they are not happy”. (154/221)	- not going to pay them on time - drugs will be higher	Delay Sell price		