LUND
UNIVERSITY

Addressing Stock Outs of Antibiotics

A Case Study of the Antibiotic Supply Chain to Tertiary Hospitals in Zambia

Markus Lundmark

Ruben Schultz

Supervisor: Lina Frennesson, Division of Engineering Logistics at LTH
Examiner: Marianne Jahre, Division of Engineering Logistics at LTH

Hosting organisation: *ReAct*

Preface

This thesis was conducted during the spring of 2021 and formed the concluding part of the authors' studies in Industrial Engineering and Management at Lund University. The thesis project was conducted at the faculty of Engineering Logistics, in collaboration with the hosting organisation ReAct.

The reasons for undertaking the study are on the author's behalf related to an interest in how supply chain management concepts can be applied in a healthcare context. We were furthermore interested in understanding how supply chain literature could suggest improvements to the impeded access to antibiotics in low- and middle-income countries (LMICs). For ReAct, gaining a greater understanding of the antibiotic supply chain leading to tertiary hospitals was beneficial as they were assisting in health system strengthening in Zambia with regards to antimicrobial resistance (AMR) during the time of the study.

Acknowledgements

We want to express our gratitude to the people and organisations who assisted us in conducting our study. We want to thank Lina Frennesson, our supervisor from the institution, for all your support and guidance throughout the project. You were always perceptive of the bigger picture, and provided us with the tools necessary to tackle the challenges we faced in conducting this master's thesis.

We also want to express our gratitude to Celina Hansson, our supervisor from ReAct Europe. Your kind support throughout the research conducted was greatly appreciated. Thank you for your enthusiasm and guidance in realising the investigation. In particular, we wish to recognise that your experience in the healthcare industry proved highly valuable to guide us in the appropriate direction and interpret our results.

Additionally, we would like to acknowledge the kind support given by Dr Mirfin Mpundu and Mpanga Kasonde from ReAct Africa. Thank you for your advice on determining our scope and method, as well as your assistance in the data collection. Your support and input was of great value to our investigation.

We also wish to express our gratitude to the people who participated in our interviews, and provided insights that informed our investigation. We appreciate that you took the time to participate in our research, especially considering the challenges currently faced in Zambia's health system as an effect of the Covid-19 pandemic.

Abstract

Title: Addressing Stock Outs of Antibiotics

Problem Description: The lack of access to antibiotics has long been raising concerns in the global health community, and 5.7 million deaths that could have been avoided with proper antibiotic treatment are believed to occur every year. Further exacerbating the issue is the diminishing effect of commonly used antibiotics, due to the silent pandemic of antibiotic resistance caused by irrational and excessive use. A key prerequisite for securing access and rational use is that health practitioners have the right set of antibiotic drugs at their disposal. This stresses the need to explain why stock outs occur, and underlines the importance of implementing effective inventory management strategies at hospitals.

Aim: The aim of the study was to investigate why stock outs of antibiotic drugs occur at tertiary hospitals in Zambia, and how these stock outs can be addressed through inventory management strategy at tertiary hospitals.

Methodology: The study comprised an embedded single-case study of the public healthcare supply chain leading to tertiary hospitals in Zambia. The study sought to explain why stock outs occur, and explore how stock outs can be addressed by conducting qualitative research on two analytical units: the healthcare supply chain in Zambia, and tertiary hospitals in Zambia. The units as well as their enclosed informants were sampled purposely with the assistance of the hosting organisation. Data was collected by way of a secondary data study and in-depth informant interviews. Primary findings were triangulated with secondary data sources and analysed on the basis of the theoretical foundation established in a frame of reference.

Conclusion: The analysis emanated in an explanation of why stock outs occur, and furthermore generated hypotheses as to how stock outs can be addressed through inventory management strategy. The main cause of stock outs identified was insufficient funding, an issue that was found to permeate almost all supply chain processes. The study also illustrated that stock outs more specifically could be attributed to inefficiencies and strategic misalignments in the healthcare supply chain. In this respect, the main causes of stock outs identified in the study were: ineffective procurement, lacking order-processing and distribution capacity, non-effective inventory policies with regard to supply chain disruptions, and inaccurate forecast input data.

Our results indicated that stock outs to some extent could be remediated via inventory management strategies at tertiary hospitals. By considering the potential benefits of product classification, implementation of cycle-counting, strengthened reporting capabilities, and heightened reorder points for strategic products, the study generated hypotheses as to how stock outs can be mitigated in absolute numbers, but also minimised for antibiotics critical for service provision.

Keywords: ‘healthcare supply chain’, ‘healthcare logistics’, ‘inventory management’, ‘healthcare system Zambia’, ‘antibiotics’, ‘stock outs’, ‘availability’

Table of Contents

List of Figures

List of Tables

1. Introduction

In the introduction chapter the phenomenon that the study investigates is introduced and contextualised. Furthermore, the thesis aim and research questions are introduced together with the scope of the paper.

1.1 Background and Problem Discussion

The lack of access to essential medicines has long been raising concerns in the global health community. The World Health Organisation estimates that nearly two billion people world-wide lack access to essential medicines (World Health Organization, 2017a). The high incidence of stock outs of essential medicines is a particularly pressing issue in LMICs, with several studies placing the average availability far below the WHO's 80 percent availability goal (Cameron et al., 2009; Bazargani et al., 2014). Among the essential medicines as defined by the WHO, a key category of medicines used to treat a wide range of bacterial infections is antibiotics. Since the discovery of antibiotics, and its subsequent commercialisation, life-threatening infections, such as sepsis and meningitis, have been effectively treated using antibiotic therapy, saving millions of lives every year (Banin et al., 2017). However, the lack of access to appropriate antibiotic treatment for large parts of the global population, as well as the diminishing effectiveness of commonly used antibiotics due to the onset of antibiotic resistance, is having a profound impact on disease control. The lack of access to appropriate antibiotic drugs has many causes, among them poor or limited availability of a sufficiently large arsenal of antibiotic drugs at the disposal of health practitioners at healthcare facilities. A key prerequisite for access is therefore availability (Laxminarayan et al., 2016), i.e. absence of stock outs, which in turn requires strong healthcare supply chains (World Health Organization, 2017a; Moons et al., 2019).

The global pharmaceutical supply chain is highly complex, and stock outs on a national level can sometimes be attributed to disruptions upstream in the supply chain (Cogan et. al 2018). Nonetheless, there are reasons to believe that many reasons behind national stock outs are internal to the country where the stock outs have occurred. In fact, a study of the reasons behind national stock outs of vaccines in the WHO member countries showed that 80 percent of the stock outs were due to reasons internal to countries (Lydon et al., 2017). The issue can be narrowed down further, as these internal reasons stand to show that stock outs are not solely caused by nation-wide shortages. In some instances, drug availability is not impeded so much on a national level as it is on a regional or even local level (Bhattacharya et al., 2019). This suggests that the problem can partly be traced to ineffective supply chain operations, such as a prevalence of bottlenecks in last-mile distribution and inventory management practices at health facilities. To pinpoint the causes of stock outs is notoriously difficult, as the lacking availability could be caused by a multitude of factors.

In Zambia, several studies point towards stock outs of antibiotics being a common occurrence at both hospitals and health centres, constituting a major impediment to the provision of quality care to the citizens of the nation (Picazo and Zhao 2009; Vledder et al. 2015; Axios International, Inc., 2017; Ooms et al., 2020). All levels of care are affected, from rural health centres to tertiary hospitals (Axios International, Inc., 2017). Tertiary hospitals are also referred to as third-level hospitals. These facilities provide specialised and advanced care, implying that treatments at these facilities require a wide array of

antibiotic drugs (MoH, 2013). In recent years, the Government of the Republic of Zambia (GRZ) has made substantial efforts to increase availability of essential medicines, by reforming the healthcare supply chain. The newly reformed healthcare supply chain is managed by the MoH together with its cooperating partners and the Zambia Medicines and Medical Supply Agency (ZAMMSA). ZAMMSA is a parastatal company fully owned by the MoH and MoF, responsible for the procurement, distribution and storage of health commodities in Zambia (Zambia Medicines and Medical Supplies Agency Act, 2019).

The MoH, together with ZAMMSA and other key actors, have tried to identify prioritised areas where targeted interventions effectively can strengthen the supply chain to prevent stock outs (MoH, 2015a). Several of these interventions form part of the inventory management in the supply chain, and strengthening the inventory management at the points-of-services is explicitly listed as a key priority moving forward (Ibid.). The need for strengthening the inventory management was also highlighted in the USAIDs 2018 Supply Chain Assessment in Zambia (Axios International, Inc., 2017). The assessment also concluded that inventory management capabilities at health centres and hospitals were usually weaker than at the central level (Ibid.).

The fact that notable stakeholders have raised concerns about antibiotic stock outs at hospitals, with specific reference to the need for stronger inventory management practices at hospitals, points at the potential to make contributions to practice in Zambia. Furthermore, most of the body of literature on the subject concerns the healthcare supply chain in Zambia prior to the substantial reforms it has gone through. This suggests that the application of inventory management strategy in the Zambian healthcare supply chain context in its current state is a field of research that largely remains unclear.

1.2 Introduction to Hosting Organisation

ReAct is a global independent network dedicated to articulating the nature of antibiotic resistance, and creating pathways to combat it. ReAct aims at engaging the international community to act to halter the growing threat of antibiotic resistance. The organisation promotes change through three main channels: (i) raising awareness about the issue and its complexity, (ii) encouraging and engaging stakeholders to act, and (iii) influencing policy making, promoting coherent, inclusive and sustainable regulation of antibiotic use on an international, national and regional level. The organisation works closely with national actors to develop and implement national action plans and antimicrobial stewardship programs. Their engagement also includes promoting sustainable and equitable access to antibiotics, and accordingly, functional antibiotic supply chains. In this respect, the organisation states that *"functional supply chains can promote public and animal health by increasing program impact, enhancing quality of care, improving cost effectiveness and efficiency"* (ReAct, 2021). Moreover, the organisation underlines that *"the supply chain of pharmaceutical products relies on several activities including product selection, quantification and procurement, and inventory management, storage and distribution"* (Ibid.).

At the time the study was conducted, ReAct worked closely with MoH, tertiary hospitals and other stakeholders in Zambia towards coordinating the response to AMR. In this enterprise, there was a need to understand the antibiotic supply chain in Zambia, as well as its possible shortcomings. The study was

conducted in collaboration with ReAct Europe, situated in Uppsala, Sweden, and ReAct Africa, situated in Lusaka, Zambia.

1.3 Aim

This study aims to investigate why stock outs of antibiotic drugs occur at tertiary hospitals in Zambia, and how these stock outs can be addressed through inventory management strategy at tertiary hospitals.

1.4 Research questions

In light of the problem discussion and thesis aim, we intended to extend the current body of literature that explained the causes of stock outs in the Zambian healthcare supply chain. This raised research question one:

> **RQ1:** *Why do stock outs occur at tertiary hospitals in Zambia?*

Research question one seeks to identify causes of antibiotic stock outs at tertiary hospitals. Answering research question one necessitated an investigation of the healthcare supply chain in its entirety, since stock outs at one node could be attributed to shortcomings at another node. In consequence, research question one addressed a problem that occurs at hospitals, but can be explained by studying the healthcare supply chain as a whole. We addressed research question one by investigating the healthcare supply chain context in Zambia, in addition to the current healthcare supply chain strategies, with the objective of identifying possible shortcomings. In order to understand what research question one seeks to enquire, we considered it prudent to not only define the nature of the query, but also the nature of the answer sought. Research question one is explanatory in nature, where we sought to explain the phenomenon of antibiotic stock outs. According to the logic presented by Zainal (2007) and Stebbins (2001), this means that answering research question one entails arriving at conclusions that explain the causal relationship between stock outs and supply chain shortcomings.

Furthermore, the research conducted in this study sought to explore how inventory management strategies employed at tertiary hospitals in Zambia could attend to shortcomings in the healthcare supply chain that were identified to cause antibiotics stock outs. This raised research question two:

> **RQ2:** *How can stock outs of antibiotics at tertiary hospitals be addressed through inventory management strategy?*

Research question two promoted an investigation of how inventory management strategies could supposedly be applied in the Zambian context to address stock outs. We addressed research question two by investigating current inventory management strategies at tertiary hospitals in Zambia, with the objective of identifying possible shortcomings or obstacles to achieving antibiotic availability. These shortcomings were analysed in conjunction with healthcare supply chain literature, in order to suggest potential improvements to the inventory management strategies currently employed at the hospitals. In contrast to research question one, research question two is exploratory in nature. According to the logic

presented by Zainal (2007) and Stebbins (2001), this means that answering research question two entailed generating hypotheses for how stock outs can be addressed through inventory management strategy.

1.5 Scope

This study aims to explain why antibiotic stock outs occur at publicly managed tertiary hospitals in Zambia, and generate hypotheses as to how inventory management strategies at the hospitals can address stock outs. As such, the study sought to identify the connection between stock outs and aspects pertaining to the public healthcare supply chain context in Zambia as well as the strategies employed in the healthcare supply chain. The study was limited to investigating stock outs occurring at tertiary hospitals in Zambia. Delimiting the study to tertiary hospitals served two purposes. First of all, tertiary hospitals constitute a considerably more uniform or homogenous sample as compared to hospitals in general, simplifying sampling and strengthening the validity of findings (Guest et al., 2006). At the time the study was performed there were six tertiary hospitals in Zambia, with catchment areas collectively covering the entire nation.

The study attempted to map the antibiotic supply chain, from procurement to tertiary hospitals. The study was designed as a single-case study. The analytical units embedded in the case included tertiary hospitals and actors in the healthcare supply chain leading to tertiary hospitals. This is illustrated in Figure 1.1. As the case encompassed the complete public healthcare supply chain in Zambia, it was naturally geographically limited to the same domain. Data was collected from distinct units of observation that could build theory that was relevant to tertiary hospitals in Zambia in general. To pursue representativeness and external validity of the case-study results to the greatest possible extent, findings were triangulated from several primary sources (informant interviews), and secondary sources. Research was conducted between January 2021 and May 2021, and interviews took place in March and April.

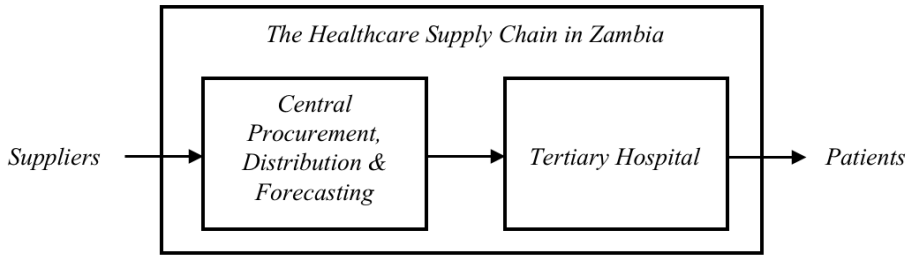

Figure 1.1 - The scope of the case study, illustrating the units of analysis embedded in the case.

There were some delimitations to the study. For example, the study was limited to the flow of antibiotics to health facilities, implying that return flows were not investigated. Neither was the quality of the drugs in the supply chain. Furthermore, the study did not consider antibiotic wastage from damage, theft, and expiration. This delimitation was not considered to undermine the internal validity of the results, as previous research had indicated that this only constituted a minor issue in Zambia (Axios International, Inc,. 2017). While several interviewed informants indicated that central-level warehousing operations

were a bottleneck, we decided to omit an in-depth investigation of possible shortcomings in the warehousing operations, instead observing the implications of the central warehouse constituting a bottleneck. This decision was also supported by the resource limitations imposed on the study, as well as the fact that the Covid-19 pandemic complicated observation of actual practice at the central warehouse.

While supply chain risk management is a developed field within healthcare logistics and while Zambia is exposed to supply disruption risks with regard to their antibiotic supply, the study was delimited to investigating remediation strategies belonging to the domain of inventory management strategies at tertiary hospitals. Nevertheless, we recognise that supply chain risk management could be an alternative or viable complement to strategies investigated in this paper.

1.6 Thesis Outline

This thesis seeks to address the issue of antibiotic stock outs at tertiary hospitals in Zambia, by conducting case research on the healthcare supply chain in Zambia. The study investigated why stock outs occur, in addition to how stock outs could be addressed through inventory management strategies. The thesis is structured around six main sections. The first section is the introduction, where the problem that the thesis is addressing is formulated, as are the aim and research questions that guide the study. The second section is the frame of reference, where a theoretical foundation for the study is established. This section also serves to exhibit previous research on the topic, exposing possible gaps in theory and practice to which the thesis can make a meaningful contribution. The third section is constituted by the methodology, where the research approach and method is explained. The methodology section serves as a guide for how empirical research was conducted towards answering the thesis' research questions. In the fourth section, empirical data, the research findings are presented. The exhibit of empirical data is formatted like the frame of reference to aid the ensuing analysis. In the fifth section, the analysis and discussion, the empirical data collected is interpreted through the theoretical lense installed in the frame of reference. The analysis and discussion section essentially attends to the research questions. The section also presents a discussion concerning the relevance of the empirical data. The sixth and final section of the thesis paper synthesises the analysis, and presents conclusions drawn from the empirical data. In this section, the research questions are answered. The conclusion also contains a discussion about the research contributions to both practice and theory, its limitations, as well as suggestions for future research.

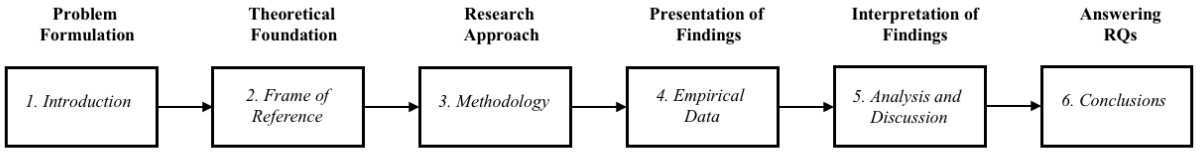

Figure 1.2 - Illustration of the thesis outline.

2. Frame of Reference

This study aims to investigate why stock outs of antibiotic drugs occur and how these stock outs can be addressed through inventory management strategies. In light of this aim, the study sought to gain insights as to how the healthcare supply chain in Zambia was designed to function, and how its possible failure to function properly resulted in stock outs. Furthermore, based on the identified typical causes of stock outs, the study sought to investigate how inventory management strategies could address the occurrence of stock outs. The issue was approached from the perspective of the two research areas illustrated in Figure 2.1: 'the healthcare supply chain context', and 'healthcare supply chain strategy'.

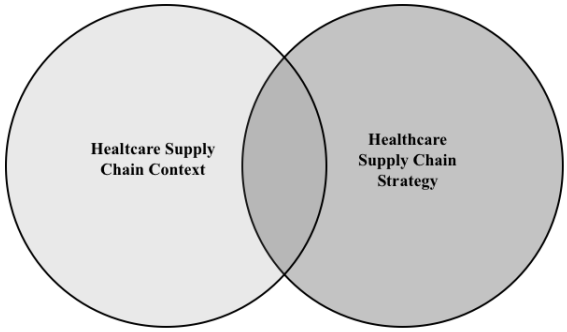

Figure 2.1 - A representation of the two research areas that were investigated.

The frame of reference serves as a theoretical foundation and installation of supply chain terminology on which the case study is built and through which answers to the research questions are sought. More specifically, the frame of reference is, as suggested by Mosey (1991, p. 851), "[an] *integrated collection of theoretically based information, organised in such a way that it provides guidelines for problem identification and remediation as it relates to specified elements of the profession's domain of concern*". In light of this suggested approach, and considering that the field of research is delineated by the interface between the healthcare supply chain context and healthcare supply chain strategy, the frame of reference was dissected into these two subsections.

The two subsections are illustrated in the herringbone diagram in Figure 2.2; 'the healthcare supply chain context' is embodied by the top of the diagram, and 'healthcare supply chain strategy' by the bottom of the diagram. The diagram illustrates how the healthcare supply chain context and healthcare supply chain strategy interact to achieve availability of antibiotics at hospitals. Considering the causal relationship between the functioning of the supply chain and drug availability, the diagram can also be interpreted as a contrapositive; if a stock out occurs, the diagram illustrates the key supply chain contextual factors or supply chain strategic factors that could be at fault.

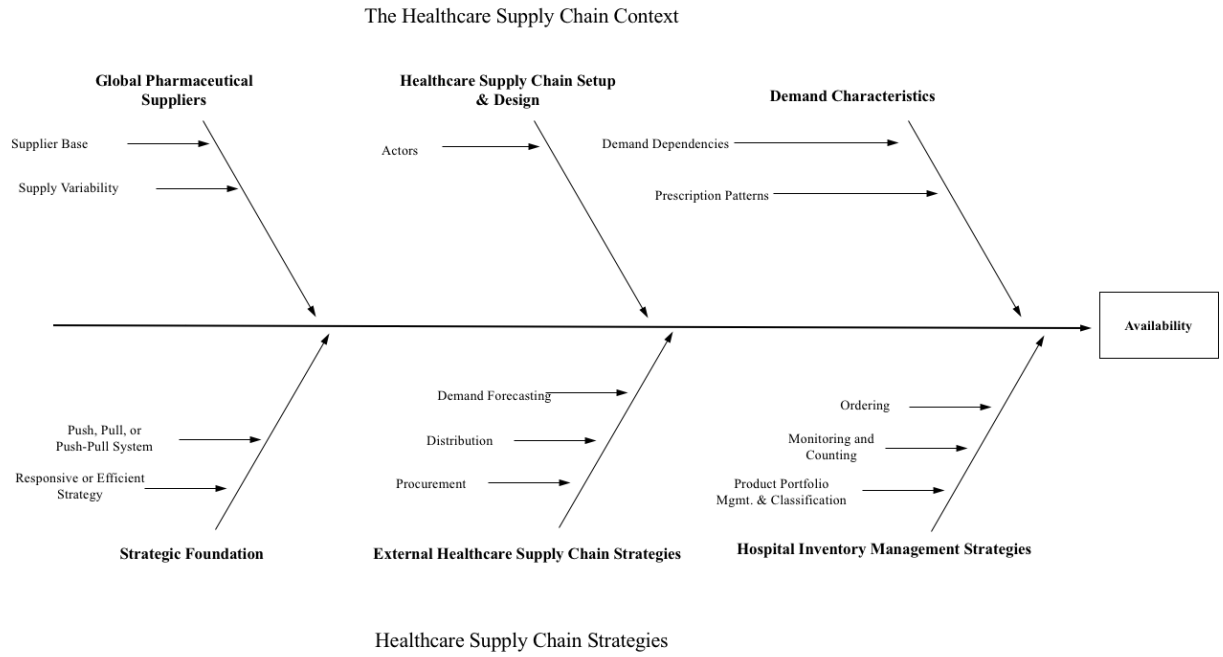

Figure 2.2 - An illustration of how supply chain strategy in the healthcare supply chain together with the healthcare supply chain context interplay to achieve antibiotic availability at hospitals.

The diagram stands to show that antibiotic availability and antibiotic stock outs can be considered two sides of the same coin. Availability signifies an inventory status where there are sufficient amounts of any given antibiotic or equivalent drug in the hospital pharmacy at the disposal of hospital personnel. Drug availability can also be approached by way of studying stock out incidence, as is suggested by (Bhattacharya et al., 2019). Accordingly, an investigation concerning the prerequisites for availability will also naturally expose possible causes of stock outs. In light of this, the two subsections of the frame of reference are presented below.

The Healthcare Supply Chain Context

The first subsection covers aspects of the healthcare supply chain context that interplay to achieve antibiotic availability. These include:

1. Global pharmaceutical suppliers, including an investigation of the supplier base, and the supply variability of the national inbound supply of antibiotics.
2. The healthcare supply chain setup and design, including aspects relating to the administrative structure of the supply chain, the supply chain actors, and their roles.
3. Demand characteristics of antibiotics at hospitals.

Healthcare Supply Chain Strategies

The second subsection establishes an understanding of how healthcare supply chain strategies achieve antibiotic availability, and specifically how inventory management strategies can be employed to remediate stock outs. As such, the second subsection of the frame of reference covers:

1. The strategic foundation of healthcare supply chains. That is, whether the healthcare supply chain follows a responsive or efficient strategy, and whether the supply chain is configured as a push, pull or a conjunctional push-pull system.

2. External healthcare supply chain strategies, with a focus on three external supply chain processes: procurement, distribution to hospitals, and demand forecasting.
3. Hospital inventory management strategies, with a focus on three identified key inventory management functions: product portfolio management and classification, ordering, and monitoring and counting.

2.1 The Healthcare Supply Chain Context

In this section, the healthcare supply chain context is investigated. The first topic under investigation is 'global pharmaceutical suppliers'. Thereafter, the scope is narrowed down to the 'healthcare supply chain setup and design'. Finally, the section 'demand characteristics' covers relevant aspects pertaining to the demand for antibiotics. The structure of the section is illustrated in Figure 2.3, where each subsection, from left to right, influences antibiotic availability at hospitals.

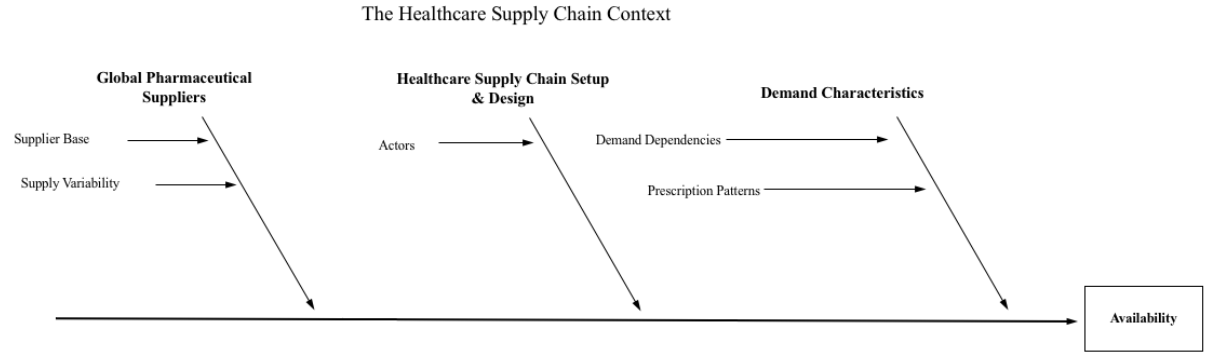

Figure 2.3 - An illustration of how the healthcare supply chain context relates to antibiotic availability at hospitals, and correspondingly, how deficiencies can lead to stock outs.

2.1.1 Global Pharmaceutical Suppliers

As antibiotics, much like other pharmaceuticals, are generally procured from international suppliers, any national healthcare supply chain is highly reliant on the global pharmaceutical supply chain (Cogan et. al 2018). The global pharmaceutical supply chain has received considerable attention over the last couple of years, not least as a direct result of the outbreak and surge of the Covid-19 pandemic (Fonseca and Azevedo, 2020). In spite of the renewed interest, the global pharmaceutical supply chain is fragmented, and disruptions such as the Covid-19 pandemic have exposed shortcomings in the resilience of the pharmaceutical supply chain (Ibid.). In fact, in many cases, ensuring a steady supply of antibiotics is conditional upon one or a few suppliers (Cogan et. al, 2018). For example, Cogan et. al (2018, p.7) mentions that "*a global shortage of the key antibiotic piperacillin-tazobactam was caused by an explosion at a Chinese factory – the single producer of the API needed to produce the medication*". As is illustrated in Table 2.1, global and national antibiotic shortages can have different root causes. Global shortages are largely caused by non-resilience in the global pharmaceutical supply chain. Aspects of non-resilience that stand out include the market failure or market exit of international pharmaceutical suppliers

as a result of low profit margins, or suppliers' over-reliance on few manufacturers, leaving the supply chain exposed to disruption risks (Cogan et. al, 2018).

Table 2.1 - A categorisation of global and national causes of antibiotic shortages, adapted from (Cogan et. al, 2018).

	Global Shortage	**National Shortage**
Description	A global shortage is signified by a lack of available international suppliers who can provide any specific antibiotic or equivalent drug.	A national shortage is signified by global availability but national unavailability for whatever reason.
Causes	Market failure or market exit of international pharmaceutical suppliers as a result of low profit margins; suppliers' over-reliance on few manufacturers; exposure to disruption risks.	Capacity or budgetary limitations of states to compete for tenders; reliance on a limited set of suppliers; shortcomings in the national healthcare supply chain.

Global stock outs as a result of a non-resilience is a real concern. However, leaving the analysis at that fails to take into account other relevant aspects pertaining to the global pharmaceutical supply chain. Even in cases when antibiotics are not subject to global stock outs, national procurement processes are still deeply affected by the state of the pharmaceutical supply chain. For example, capacity or budgetary limitations coupled with a reliance on a limited set of suppliers leave many national public procurers exposed to competitive disadvantages (Seiter, 2010; Yadav, 2015). In such instances, procurers are not seldom compelled to accept tenders with sub-optimal drug packaging or elevated prices. Seiter (2010) underlines that suppliers preying on weak procurers is a yet more pressing issue in LMICs.

While the global pharmaceutical supply chain falls outside of the scope of this paper, it has been identified to have implications on both supply variability in national healthcare supply chains, as well as product characteristics. A key takeaway is that the erratic and unreliable supply from international suppliers make the setup and design of national healthcare systems inherently complex.

2.1.2 The Healthcare Supply Chain Setup and Design

Healthcare supply chains are similar to other industry-specific supply chains in terms of their general design. In this regard, the supply chain can be modelled as a series of processes, or as a network of suppliers, producers, distributors and retailers coordinating appropriate activities to meet the demands of the final customers (Chandra & Kachhal, 2004; Landry and Beaulieu, 2013). Activities are installed to manage the three flows typically seen in generic supply chains: material, information and financial flows (Jonsson and Mattsson, 2017). In light of these similarities, but also due to the fact that the healthcare sector is *"lagging behind in adopting* [new] *logistics concepts "*, (Moons et al., 2019 p.206). Moons et al. (2019) suggest that improvements to the hospital supply chain should be approached by studying not only the healthcare sector, but also other commercial industries. The relative abundance of literature concerning commercial supply chains attests for the potential of transposing applicable commercial supply chain theories to healthcare supply chains. For example, (Moons et al., 2019) point to the potential in mimicking some of the best practices found in the manufacturing or retail industry to achieve greater

effectiveness in the healthcare supply chain. At the same time, Kwon et al., (2016) describes that the effectiveness as a primary focus is more typical for healthcare supply chains than for commercial dittos, where efficiency has a bigger emphasis.

2.1.2.1 Defining Healthcare Supply Chains

In order to build a theoretical foundation to understanding the healthcare supply chain setup and design, we compared the healthcare supply chain with the commercial ditto. When juxtaposing commercial and healthcare supply chains, as is illustrated in Table 2.2, Kwon et al. (2016) and Kwon and Kim (2018) underline that there are several fundamental differences between the two chains that render it challenging to apply or extrapolate research conducted on one chain to the other. One of the key differences in this regard, as described by Kwon et al., (2016), is that the two supply chains are distinct in terms of stakeholder relationships; whereas commercial supply chains typically are characterised by high degrees of collaboration between supply chain actors, healthcare supply chain relationships are often contractual. According to Kwon and Kim (2018) this has big implications for how the supply chain is managed and how potential improvements can be approached: "[a] *supply chain based on collaborative framework looks for a long- term value creating relationship while supply chain based on contract emphasizes a short- term fulfillment of the contents specified in the contract*" (Kwon and Kim, 2018 p.139). In light of the fact that relationships within healthcare supply chains typically are contractual, Moons et al. (2019) suggest that a key challenge for healthcare supply chains is the lack of consensus with regard to efficiency management. A comparatively high level of resource scarcity typical for the healthcare system imposes pressure on actors to pursue efficiency (Moons, et al., 2019). At the same time, actors often fail to use a collective set of key performance indicators or objectives. This issue is further aggravated by insufficient information sharing (Kwon and Suh, 2004; Moons, et al., 2019). For example, relying solely on contractual agreements between hospital inventory managers and distributors can sometimes result in unnecessary build-up of excess inventory at the hospital or even stock outs. This scenario could often have been avoided if distribution decisions and decisions relating to inventory allocation had been made in collaboration with inventory managers at the hospital (Kwon and Suh, 2004).

Table 2-2 - A juxtaposition of the typical commercial supply chain and the healthcare supply chain, adapted from (Kwon et al., 2016).

Attributes	**Commercial Supply Chains**	**Health Care Supply Chains**
Strategic Foundation	Push-pull	Foremostly Pull
Service-level Focus	Low to high degree	High degree
Relationships	Collaborative	Contractual
Regulation	Low to medium degree	High degree
Procurement Difficulty	Low to high degree	High degree

2.1.2.2 Healthcare Supply Chain Actors

Healthcare supply chains are often managed on a national level, with standard operating practices (SOPs) and decision-making mandates held by government bodies. The final link of healthcare supply chains, the hospital, can be regarded as a supply chain in its own right, emphasising that inventory at the hospital pharmacy becomes subject to internal distribution to departments and nursing units within the hospital (Landry and Beaulieu, 2013; Moons, et al., 2019).

In light of the above discussion, the healthcare supply chain was defined to be composed of two units, with definitions adapted from (Moons et al., 2019):

- the external healthcare supply chain, comprising central procurement authorities, distributors and intermediaries upstream of the hospital (Ibid.)*;*
- the hospital, comprising the hospital pharmacy (responsible for inventory management at the hospital), and bedside administration staff, (hospital departments or nursing units with clinicians who deliver treatment to the patients) (Ibid.).

These supply chain units are illustrated as a simplified generic healthcare supply chain in Figure 2.4. The figure also illustrates how inbound supply to the healthcare supply chain flows from pharmaceutical suppliers, eventually reaching the patient to whom antibiotic treatment is administered.

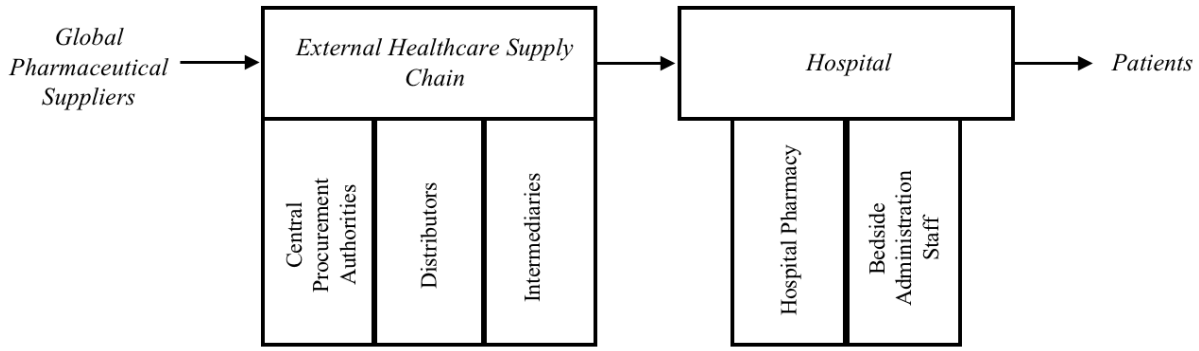

Figure 2.4 - A visual representation of a generic healthcare supply chain.

2.1.2.3 Healthcare Supply Chain Actors in LMICs

In LMICs, healthcare supply chains typically labour under different circumstances than their counterparts in high-income countries. While healthcare supply chains in high-income countries have been subjected to reforms entrenched in contemporary supply chain literature, there is a comparative dearth of literature exploring how theories can be applied to LMICs (Larson and Halldorsson, 2002; Kraiselburd and Yadav, 2012; Subramanian et al., 2020). Some of the major differences between healthcare supply chains in LMICs as compared to high-income countries concern available finances, governance, as well as the institutional and technical capacity to regulate and manage the healthcare system (Yadav, 2015). The lack of capacity and available funds make LMICs particularly exposed to the risk of falling victim to

ineffective procurement and under-funded supply chain operations (Lydon et al., 2017). In LMICs, the issue of under-funding is not only connected to the amount of funds, but the financial commitment horizon. In fact, a lack of long term financial commitment to invest in supply chain operations is a common reason behind nation-wide stock outs in LMICs (Lydon et al., 2017). The lack of long term commitment can partly be explained by the prevalence of contractual relationships between supply chain actors as opposed to collaborative value propositions, in addition to a tendency to address recurring stock outs ad hoc rather than through holistic reforms of the system (Yadav, 2015; Kwon,et al., 2016).

The lack of commitment to invest in supply chain operations can also be perceived by considering the discrepancy between increased product flow volumes and investments in supply chain operations. Over the last couple of years, the international community has seen an upsurge in global health initiatives (GHIs), with considerable investments made to capacitate international disease-specific programs (World Health Organization Maximizing Positive Synergies Collaborative Group, 2009; Yadav, 2015). While the initiatives generally have led to a dramatic increase in product flow volumes, corresponding expenditures in the healthcare supply chain have lagged behind (Cameron et al., 2009; Yadav and Smith, 2014). Yadav (2015 p.147) suggests that one of the reasons behind this phenomenon can be attributed to the fact that *"operating expenses are not a very attractive investment politically"* as opposed to capital projects. They furthermore add that this tendency *"percolates throughout the system and resource allocations from the center, province, and district, all tend to neglect adequate coverage of operating expenses"* (Yadav, 2015 p.147). It is reasonable to expect that the lack of measures to increase operational capacity increase the risk of stock outs. Furthermore, the deflated financing of operations have negative implications on the performance of other inventory management processes directed at avoiding stock outs.

The majority of sub-Saharan LMICs have a healthcare supply chain structure composed of a public central procurement authority that manages the external healthcare supply chain activities (Govindaraj and Herbst, 2010; Yadav et al., 2011; Yadav, 2015). The central procurement authority is usually responsible for using predefined public funds to procure pharmaceuticals from suppliers, a procedure that can be cumbersome and drawn out, not seldom taking up to two years (Todd D, 2011; Arne et al., 2014; Seiter, 2020) . It is worth mentioning that LMICs often lack funds to procure sufficient volumes of essential medicines to meet demand, and institutional capacity to effectively perform the public procurement tendering process (Seiter, 2010; World Health Organization 2004). Procurement tendering usually amounts to complex bureaucratic procedures, and in many LMICs surmounting the red tape is usually a challenge, sometimes to the extent that pharmaceutical companies seize the opportunity to prey on the weak bargaining power of the procurer (Seiter, 2010).

In LMICs, the complex administrative structure can render drug stock outs difficult to remediate. This is partly because of difficulties with holding the appropriate supply chain actors accountable for supply chain shortcomings. Yadav (2015) mentions that the organisational design typical of LMIC healthcare supply chains imply that accountability is fragmented, ambiguous, or diluted between supply chain actors. In many instances, regulatory authorities, government ministries and the central procurement authorities all have mandates that encompass different components of the same operations (Ibid.). As a consequence, actors may blame operational deficiencies and stock outs to the possible shortcomings of other supply chain actors (Ibid.). The fragmented accountability typical for healthcare supply chains in LMICs likely have implications on the incentives to hold inventory; if not held accountable for stock outs, supply chain

actors are more prone to factor in that surplus inventory or safety stock constitute a financial liability (Toomey, 2000).

The upsurge of GHIs since the turn of the millennium, has increased funding for these initiatives (Kickbusch, 2011). More specifically, the GHIs have directed efforts at tackling global focal diseases such as Malaria, Tuberculosis and HIV/AIDS, while simultaneously reducing health inequity between communities and nations (Biesma et al., 2009; Kickbusch, 2011). The GHIs are characterised by their ability to unite stakeholders, providing a coordinated response across national boundaries and mobilising and disbursing a large amount of financial resources to combat the focal diseases (Biesma et al., 2009). While GHIs have proven effective in raising awareness and rapidly scaling up service delivery in the health care systems where they have been implemented, the initiatives have been subject to criticism. Critical voices have pointed out the lack of country ownership and their tendency to impose parallelism and to duplicate efforts due to lack of harmonisation with the national healthcare system (Oomman et al., 2007; Parkhurst et al., 2020). This fragmentation of the supply chain and its operations risks straining the healthcare systems' resources by adding an additional administrative burden (Biesma et al., 2009). Moreover, several studies have raised concerns that the earmarked funding and imposed donor conditions by the GHIs may distort the national healthcare systems' priorities (Khan et al., 2017; Micah et al., 2018; Parkhurst et al., 2020). To increase incentive alignment between the actors in the supply chain, sector-wide approaches (SWAp) were developed in the healthcare sector in the early 1990s (Piekkari and Welch, 2012). Actors following a SWAp are expected to develop and follow a single sector policy and coordinate funding and procurement under government leadership (World Health Organization, 2000). A study conducted in Tanzania and Zambia showed that none of the GHIs and its implementing partners operating in the countries adequately followed the SWAp mandating the local MoH leadership, but rather operated predominantly following their internal committees and structures (Mwisongo, Soumare and Nabyonga-Orem, 2016).

2.1.3 Demand Characteristics

Establishing accurate forecasts for future demand remains one of the chief difficulties with regard to effectively managing drug inventory in the healthcare supply chain (Rachmania and Basri, 2013). This is partly due to the demand for items used in the healthcare system being highly complex. The complexity stems from a high degree of uncertainty caused by a number of factors such as: the physicians' prescription behaviours, the patients' particular response to the prescribed treatment, the disease panorama in the hospitals' catchment population areas and demand dependencies between items (Doubova et al., 2007; Montoya et al., 2010; Vila-Parrish et al., 2012). While the aforementioned factors are true for most healthcare items, some factors pose an especially strong influence on the demand for antibiotic drugs. These include diagnostic uncertainties and the prevalence of AMR in the area where the hospital operates.

When hospitals lack diagnostic capacity, the bacterial strain responsible for the patient's condition cannot be isolated, leading to diagnostic uncertainty. According to Wang, Liu, Zhang and Liu (2021), this may lead to an increased use of antibiotics. The tendency of increased use is especially prominent for broad spectrum antibiotics, due to their viability to be administered as empiric treatment (Broom and Broom, 2018). This means that they are effective against a wide array of bacterial strains, and form a viable option for situations when a specific bacterial diagnosis cannot be established. The prevalence of AMR in

bacterial pathogens in the area can also affect the prescribing patterns, and by extension, the demand for antibiotics, as an alternative treatment has to be prescribed when AMR causes the first-line treatment to fail.

The mix and extent of antibiotic usage has been shown to differ between regions, and Filippini et al. (2007) argues that this cannot only be explained by the levels of AMR in the region, but rather is constituted by the doctors' attitude and preferences as well as economic incentives and the price of antibiotic drugs (Filippini et al., 2007). In their research, Filippini et al. (2007) conclude that there is a significant seasonal component to the mix of antibiotics being prescribed, with a higher ratio of more expensive, broad-spectrum antibiotics being prescribed during winter and a larger share of less expensive, narrow-spectrum antibiotics during summer. The researchers argue that this might be caused by the physicians' risk aversion during periods when infections are common. Additionally, when calculating the substitution effect, they find that antibiotic drugs can act as both complementary and substitute products to one another (Ibid.) The result is to be expected, as treatment guidelines may list several antibiotic drugs as suggested first and second line treatment. Supporting this notion, a survey study from hospitals in Europe found that 46 percent of antibiotic stock outs "often or always" led to the use of an equivalent substitute drug (Pauwels et al., 2015).

2.3 Healthcare Supply Chain Strategies

This section presents how healthcare supply chain strategies achieve antibiotic availability, and specifically how inventory management strategies can be employed to remediate stock outs.

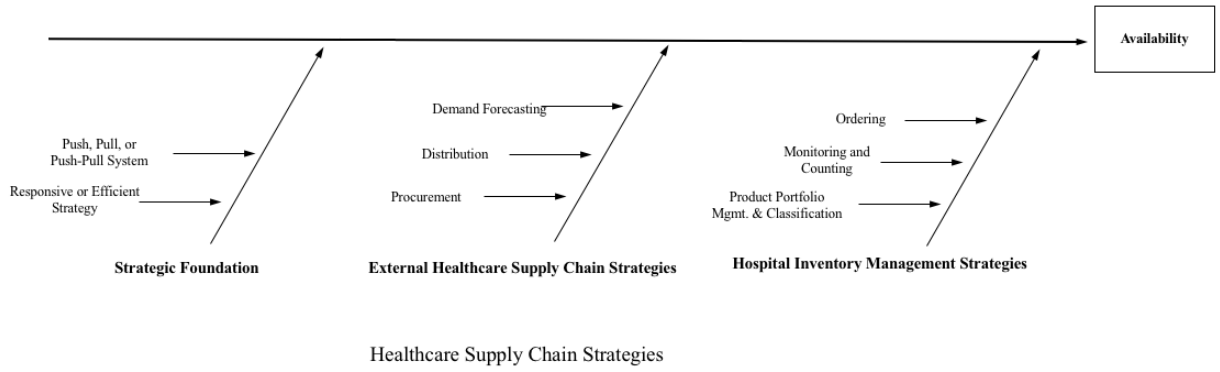

Figure 2.5 - An illustration of how the healthcare supply chain strategies work towards achieving antibiotic availability at hospitals, and correspondingly, how they can address stock outs.

2.3.1 Strategic Foundation

Healthcare supply chain strategy, on a broader level, concerns itself with increasing operational efficiency, and minimising inventory holding and distribution costs, without jeopardising patient service levels (Kwon et al., 2016). There are multiple overarching supply chain strategies that are typically used

to address this trade-off (Mbhele, 2016; Moons et al., 2019; Bvuchete et al., 2020). These strategies can not be regarded as isolated concepts or dichotomies. In fact, the concepts are often used in conjunction with one another (Birhanku et al., 2014; Mbhele, 2016). For example, a prerequisite for an efficient pull system is supply chain responsiveness, necessitating the simultaneous implementation of both strategies (Mbhele, 2016). Correspondingly, a prerequisite for push or conjunctional push-pull systems is robust forecasting processes and the utilisation of economies of scale (Klug, 2006; Rossin, 2012; Mbhele, 2016). These overarching strategies that form the strategic foundation are presented separately in the subsections below.

2.3.1.1 Responsive Versus Efficient Supply Chain Strategies

According to Moons et al. (2019), the traditional healthcare supply chain strategy for material flows is characterised by holding a large amount of stock while keeping the frequency of deliveries comparatively low (Birhanku et al., 2014). This results in low ordering and transportation costs at the expense of elevated costs of holding and managing stock (Moons et al., 2019). The tendency to elevate inventory levels to ensure that demand is met accurately and timely is typical of a responsive strategy (Birhanku et al., 2014; Bvuchete et al., 2020). To shed light on the inventory managerial implications of a responsive strategy, it is relevant to introduce and define the concepts of 'responsive' versus 'efficient' supply chains.

- A responsive supply chain strategy entails hedging for uncertainties such as demand spikes, often translating to comparatively high inventory levels, the maintenance of buffer distribution capacity, in addition to investments directed at decreasing lead times (Birhanku et al., 2014).
- An efficient supply chain strategy entails optimising capacity utilisation, often translating to a reduction of inventory levels (Birhanku et al., 2014).

The financial implications of the two strategies are also important to consider. Much as the name suggests, cost efficiency is at the heart of the efficient strategy (Birhanku et al., 2014). The responsive strategy, on the other hand, has service-level fulfillment as a primary objective (Birhanku et al., 2014). The costs incurred by a responsive strategy can largely be attributed to buffer inventory, but also its reliance on supporting activities; in order to reap the benefits of a responsive strategy the actors of the supply chain must cooperate to enhance inventory visibility and unfaltering replenishment processes (Bvuchete et al., 2020).

It is reasonable to induct that a focus on responsiveness as opposed to efficiency in healthcare supply chains to some extent can be attributed to the fact that demand typically is erratic, and the fact that the product flow from suppliers typically likewise is erratic. In fact, Gebicki et al. (2013) point out that erratic supply is a defining characteristic of healthcare supply chains, implying that items are not consistently available for ordering from immediate suppliers. Unavailability on a central level results in considerable variations in lead times of the hospitals' replenishment orders, rendering the hospital's inventory notoriously difficult to manage (Gebicki et al., 2013).

2.3.1.2 Push, Pull or Push-Pull Supply Chain Strategies

As previously mentioned, the healthcare supply chain is typically configured foremostly as a 'pull model' (Kwon et al., 2016). This means that the flow of goods is incited by patient demand (Mbhele, 2016), or if you will, by a proxy for patient demand: orders made by bedside administration clinical staff (Jonsson

and Mattsson, 2017; Moons et al., 2019) . Moons et al. (2019) claim that a reliable pull system indeed optimises supply chain flows, a claim echoed by Byrnes (2004), who also indicates that the model has the potential to increase service levels to patients (Byrnes, 2004; Moons et al., 2019). While this notion seems to be widespread, there seems to be a lack of consensus regarding whether or not this model is optimal as compared to other alternatives (Spearman and Zazanis 1990; Mahapatra et al., 2012). As an alternative to the pull system, Mbhele (2016) and Jonsson and Mattsson (2017) offer two additional supply chain models, thereby distinguishing three alternatives:

- the 'pull model', where product flow is incited by orders made by bedside administration clinical staff,
- the 'push model', where product flow is incited by orders made by actors upstream in the supply chain, based on forecasts of consumption, or
- the conjunctional 'push-pull model', a combination of the push and pull models, where product flow upstream of a pre-decided decoupling point[1] in the supply chain is incited by way of a push system, and product flow downstream is incited through a pull system (Mbhele, 2016; Moons et al., 2019).

The lack of consensus with regard to supply chain models suggests that a pull system is not a silver bullet to combat problems compounded in the healthcare supply chain, but rather, that the advised solution varies from case to case. Mbhele (2016) explain that the possibly poor performance of the respective models does not necessarily speak for the ineffectiveness of the models per se, but rather that prerequisites for the model to function properly are not fulfilled; for example, poor performance of the pull system can be attributed to unresponsiveness, poor timing, insufficient information sharing or poor planning across the supply chain (Mbhele, 2016). Similarly, poor performance of the push system can be attributed to it being conditional on reliable forecasts, without which actors upstream in the supply chain cannot properly gauge needs downstream in the supply chain (Mbhele, 2016).

Many researchers within the field of healthcare logistics point to the potential gains in configuring the healthcare system as a pull system (Bvuchete, 2020). However, Bvuchete et al. (2020) mentions that it is challenging to implement an effective pull system in healthcare supply chains due to the typically long lead times, and the fact that accurate demand signals often do not reach central procurement authorities and distributors. This can jeopardise stock availability, especially in scenarios compounded by supply chain uncertainty (Ibid.). With respect to this, (Liu et al., 2020) showed that the supply uncertainty was more influential than demand uncertainty in whether a pull or push-pull model was more optimal for effective service level fulfillment. In order to mitigate the risk for stock outs, supply chain managers can be impelled to increase safety stock levels (Kwon et al., 2016). At the same time, this can incur high inventory holding costs, and result in inefficient operations (Ibid.). However, Wilding (1998) offers a contrasting picture, challenging the notion that high inventory levels are financially inefficient. He suggests that it, in fact, can be financially sound to keep high levels of safety stocks despite the increase in holding costs: over-ambitiously low inventory levels can stir chaos through stock outs and irregular ordering and reordering, generating operational costs greater than the holding costs of surplus inventory (Wilding, 1998).

[1] The decoupling point also serves as a strategic positioning of buffer inventory.

Shedding more light on the picture, Mahapatra et al. (2012) compare the pull model with the conjunctional push-pull model, suggesting that *"the relative advantage of the two policies,* [push-pull and pull respectively]*, is dependent on the type of uncertainty, the level of uncertainty, the inventory control policy and the performance measures of interest"* (Mahapatra et al., 2012 p.1). A comparison between the push-pull and the pull model, elaborating on aspects and trade offs pertaining to model suitability, model focus, prerequisites for model efficacy, and consequences for the supply chain's performance is illustrated in Table 2.3. While the conjunctional push-pull system obviously includes elements of the push ditto, the strict push model is not included in the comparison, due to the fact that it is an uncommon system in the healthcare sector, as is pointed out by (Kwon et al., 2016).

Table 2.3 - A comparison between pull systems and push-pull systems.

	Suitability	**Focus and Prerequisites**	**Consequences**
Pull System	More suitable for coping with high demand variability (Liu et al., 2020) Less suitable when there is potential to utilise economies of scale (Klug, 2006; Rossin, 2012)	Emphasises responsiveness in the upstream supply chain operations (Mbhele, 2016) Emphasises information-sharing between supply chain actors to enable day-to-day operations (Mbhele, 2016) Emphasises shared incentives (Mbhele, 2016) Entails a more decentralised information flow structure (Marquès et al., 2009)	Can lead to higher fill rates at point of service (Mahapatra et al., 2012) Less sensitive to forecast errors compounded by bias or demand variability (Mahapatra et al., 2012) Can risk leading to longer lead times (Liu et al., 2020) Can imply a more erratic capacity utilisation upstream in the supply chain (Liu et al., 2020) Can risk leading to stock outs if order handling capabilities at downstream supply chain nodes are weak (Yadav et al., 2011).
Push-pull System	Less suitable for coping with demand variability (Liu et al., 2020) More suitable if there is potential to utilise economies of scale (Klug, 2006; Chung, 2009; Rossin, 2012)	Emphasises reliable forecasts (Mbhele, 2016) Emphasises information sharing between supply chain actors to avoid 'bullwhip effects' (Hartono et al., 2010; Rajaguru & Matanda, 2013; Mbhele, 2016) Entails a more centralised information flow structure (Marquès et al., 2009)	Lead time uncertainties and demand uncertainties affect upstream nodes in a greater degree (Mahapatra et al., 2012) Risk accumulation of surplus inventory at the decoupling point, harming efficient operations and counteracting benefits of low total inventories (Mahapatra et al., 2012; Mbhele, 2016) Can render it difficult to manage a large product mix, if the decoupling point is located too far downstream (Mason-Jones et al., 2000) Can render it difficult to handle high demand variability, if the decoupling point is located far downstream (Mason-Jones et al., 2000; (Mbhele, 2016) Can enable a more stable capacity utilisation upstream (Liu et al., 2020)

2.3.2 External Healthcare Supply Chain Strategies

After introducing the strategic foundation of the healthcare supply chain, this chapter presents core external healthcare supply chain strategies, namely procurement, distribution and forecasting. The nodes in the external healthcare supply chain and their corresponding functions are illustrated in Figure 2.6.

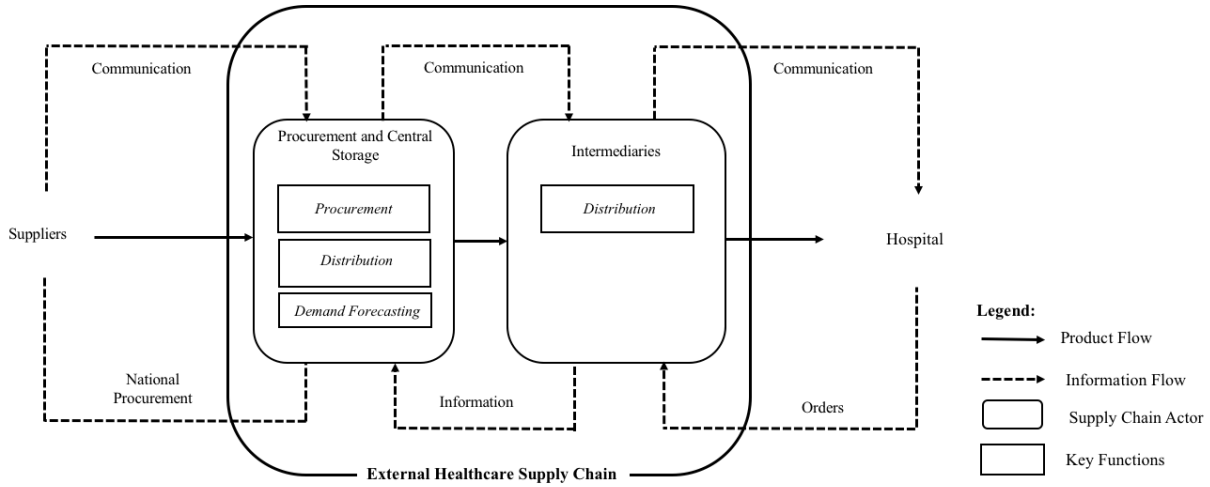

Figure 2.6 - A visual representation of the external healthcare supply chain and its core supply chain functions.

2.3.2.1 Procurement

Procurement management is a discipline that has been receiving increasing attention over the years, and the procurement function has shifted from being regarded as primarily operational to undertaking a more strategic role (Schiele, 2018). Today, procurement is often seen as a function that can serve a purpose not only by cutting costs, but by adding value to the organisation through managing its supplier relations (Van Weele, 2019).

A concept that is widely used in procurement literature and deemed important to understand procurement strategy is the purchaser's relative power vis-a-vis the supplier (Caniëls and Gelderman, 2007; Van Weele, 2019). In fact, almost every procurement portfolio model takes this into account to advise how a purchaser should manage its supplier portfolio (Dubois and Pedersen, 2002).

In the healthcare supply chain, the procurement of pharmaceuticals to the public healthcare system is typically performed by a central procurement authority using predefined public funds. The purchasing power of the procurement authorities are often weak, especially so in LMIC, chiefly because of two reasons. First, procurement authorities often lack the funds to procure sufficient volumes of essential medicines to meet demand (World Health Organization, 2004; Seitler, 2010). In fact, the failure to pay suppliers is sometimes found leading to stock outs of medicines even in developed countries (Dill and Ahn, 2014; Heiskanen et al., 2017). Furthermore, countries with high credit risks or high perceived risk of payment default are generally obliged to pay higher prices for procured medicines (Barbosa and Fiuza,

2011). Second, the number of pharmaceutical suppliers is often limited, and the few suppliers use their market control as leverage against the purchasing parts (Huff-Rousselle, 2012).

A commonly used strategy to increase purchasing power and make use of economies of scale is to form buying consortiums and consolidate the purchases, and subsequently, the purchasing power of several companies (Van Weele, 2019). This is a method that has been receiving increasing attention in the healthcare context with the increasing number of GHIs acting as global institutional procurers of medicines to combat their target diseases. This is referred to as pooled procurement (Silverman et al., 2019; Swaminathan and Deshpande, 2021). Procurement through means of pooled procurement has the potential to dramatically decrease the prices paid for the procured medicines (Silverman et al., 2019;Swaminathan and Deshpande, 2021). However, the results of these initiatives have not been entirely positive. While the focus on specific diseases have resulted in a dramatic improvement with regard to availability of treatments to these specific diseases, other essential medicines have not seen the same improvement due to an absence of attention and funding (Seiter 2010), and critical voices have pointed out the lack of country ownership and their tendency to impose parallelism and to duplicate efforts due to lack of harmonisation with the national healthcare system (Oomman et al., 2007; Parkhurst et al., 2020). To counter these effects Huff-Rousselle (2012) suggests that the pooled procurement systems should be established within existing regional or international institutions of which the engaged country feels some sense of owner- and membership.

Currently, there is no global pooled procurement mechanism coordinated by an institutional procurer in place for antibiotics, although recommendations have been made to institute such a procurement mechanism (Cogan et. al, 2018; GARDP, 2019) . Cogan et. al (2018) argue that the lack of a pooling initiative complicates securing supply. It furthermore renders demand more unpredictable for antibiotic suppliers (Ibid.). This translates to a lack of incentives for maintaining a stable production of antibiotics (Ibid.).

However, not all problems can be solved by centralising and pooling procurement. Yadav (2015) suggests that decentralising parts of the procurement functions downstream in the supply chain to health facilities or regional offices can promote a healthy degree of competition in the supply chain. While decentralised procurement may result in quality standards being more difficult to enforce and increased supplier cost, Yadav (2015) argues that the competitive pressure strengthens the incentives for improvement in the supply chain and increases both the flexibility and swiftness of procurement.

Literature also suggests that the sequencing of the procurement procedure can pave the way for operational inefficiencies or prolonged lead times (Natarajan and Swaminathan, 2014; Yadav, 2015). As the procurement cycle is triggered as funds are transferred to the procurement authority by the national treasury or an NGO, the lead time of the procurement cycle is highly dependent on the operational efficiency in the transactions with other actors in the system (Natarajan and Swaminathan, 2014; Yadav, 2015). As a result, the long procurement cycle of one to two years can be heavily delayed, rendering the product flows from suppliers arbitrary and difficult to integrate in the inventory planning. Despite these interdependencies between actors, in terms of the mandate to procure goods, the national central procurement authorities are in many instances autonomous to a certain degree. With regard to this, Yadav (2015) suggests that a greater degree of autonomy with regard to the management of the central

procurement authority is connected with more sound financial management and an increased flexibility in contractual relationships with suppliers.

2.3.2.2 Distribution

A supply chain consists of its actors, their internal processes and the flows between them. The most tangible flow in a supply chain is the material flow of products through its distribution network.

In the most simple structure of a distribution network, there is only one supplier and stock is delivered to the customer directly. This structure is commonly extended by intermediary actors or facilities used for storage or cross-docking operations. By making use of cross-docking strategies, where inbound trunking shipments are immediately transferred to downstream delivery without being stocked in between, research suggests that responsiveness can be improved while reducing the inventory levels in the system (Kreng and Chen, 2008). Compared to a distribution network where stock is prepositioned at regional hubs, cross-docking systems entail a more direct linkage between supply and demand (Kwon et al., 2016). This is because no buffer storage is kept in between the supplier and the final node, and research suggests that this may increase the need for safety storage at the point of service (Waller et al., 2006; Benrqya et al., 2014).

Optimising flows within a distribution network is centred around the scheduling of its transportations and understanding how distribution can be aligned with the overall strategy of the supply chain. In order to cope with uncertainties, healthcare supply chains in LMICs typically hold a large amount of buffer inventory at various levels of the supply chain (Yadav, 2015). This is done while keeping deliveries comparatively infrequent (Ibid.). The distribution capacity is often limited, and as a consequence, it is not uncommon for health facilities to pick up their own stock at the upstream warehouse (Ibid.). Because of the limited distribution capacity, stock outs may occur at the points of services even when there is sufficient stock within the country. This was shown in a study from 2016, where substantial stock outs at the facility level occurred despite stock being available at the central procurement authority's warehouse (Leung et al., 2016). This highlights the role of distribution and operational efficiency in the supply chain link between the central procurement authority and the hospital.

The scheduled distribution orders are usually complemented with fallback systems for when routine replenishment orders cannot be fulfilled. In these situations, it is generally preferred for hospitals to divert to expediting, i.e. placing emergency orders, or sourcing from alternative suppliers or neighboring hospitals, as compared to solely relying on backorders (Saha and Ray, 2019). However, a systematic and recurrent use of emergency orders is not considered advisable, as it risks leading to increased costs and subpar service levels (Saha and Ray, 2019). As neither backorders nor a recurrent use of emergency orders is recommended, calibrating the system of routine deliveries so that it is able to meet most of hospitals' demand for replenishment is key.

2.3.2.3 Demand Forecasting

According to Rachmania and Basri (2013), the most common forecasting technique used in healthcare systems to determine future demand for a specific drug through analysis of historical consumption of the

same drug. In terms of basing forecasts on consumption data, the challenge is twofold; first of all there is the issue of predicting future demand based on complex consumption patterns, and then there is also the issue of accurately monitoring said consumption patterns (Rachmania and Basri, 2013). The need to monitor consumption varies across different classes of products. For example, for high-consumption value items, consumption should ideally be monitored and reported on a regular basis to enable forecasts that reflect demand to enable frequent ordering and low safety stocks (Vila-Parrish and Ivy, 2013). At the same time, forecasts for items of moderate and low consumption value can to a large extent be based on historical data or estimates. In assessing how well healthcare supply chains can cope with emergency demand spikes, Duclos (1993) recognised that the frequency by which consumption is reviewed is influential with respect to avoiding stock outs (Duclos, 1993).

Sarley et al. (2009) indicate that the monitoring of consumption is often not performed systematically but rather performed impromptu or provisionally through surveys. USAID (2012) suggests that issue data, i.e. delivered replenishments, is often used instead of consumption data in LMICs due to a lack of monitoring capacity. A propos causes stock outs and forecasting, Yadav (2015 p.147) mentions that *"in the absence of periodic stock and consumption information, supply chain planning is conducted based on estimates drawn from outdated assumptions"*, which obviously jeopardises the accuracy of forecasts that other supply chain processes rely so heavily on.

Even in systems where consumption data can be adequately captured, using it as an indicator of demand is somewhat precarious; a lacking supply availability implies that there can be a discrepancy between the actual demand and what is being consumed (Gebicki et al., 2013). This means that despite efforts to monitor consumption more meticulously, or improve the mathematical models, using consumption data as input in the model simply will not reflect the actual demand. For example, if clinical staff were to prescribe Amoxicillin to a patient, before finding that Amoxicillin currently is out of stock, the subsequent consumption of a substitute antibiotic will not manifest the demand for amoxicillin. There are, however, forecasting techniques that can handle these discrepancies to some extent by taking positive and negative and negative externalities into account, i.e. the demand interdependence between items (Zhang et al., 2019). For example, Anupindi et al. (1998) and Smith and Agrawal (2000) presented models where the effects of stock outs and product substitution were included, and Conlon and Mortimer (2013), proposed a forecast model in which changes in product availability were taken into account for systems using periodic review to monitor inventory availability. However, these models have mainly been tested in retail supply chains. In healthcare supply chains, data triangulation is generally performed with morbidity and demographic data to detect distorted forecasting data (USAID, 2012).

While the goal of forecasting ultimately comes down to quantifying future demand at the final stage of the supply chain, it is difficult to isolate prerequisites for forecast efficacy to the final supply chain node. In fact, supply chain integration and information sharing is a highly relevant theme to pursue in order to avoid demand signal distortion as forecasts are shared with upstream actors (Carbonneau et al., 2008). More specifically, Vila-Parrish and Ivy, (2013) suggests that enhancing inventory visibility between hospitals and their immediate upstream supply chain actors holds great potential for conveying accurate demand signals upstream,while also enabling holistic decision making in response to supply chain disruptions, in addition to more optimised inventory allocation in the healthcare supply chain as a whole (Vila-Parrish and Ivy, 2013). The issue of inventory visibility is in this latter regard, a yet more relevant

aspect to consider as the aggregate supply of pharmaceuticals within the entire healthcare supply chain is finite (Vila-Parrish and Ivy, 2013).

2.3.2 Hospital Inventory Management Strategies

After introducing the strategic foundation of the healthcare supply chain and the supply chain strategies employed in the external supply chain, this section zooms in on hospital inventory management strategies, as presented in Figure 2.7.

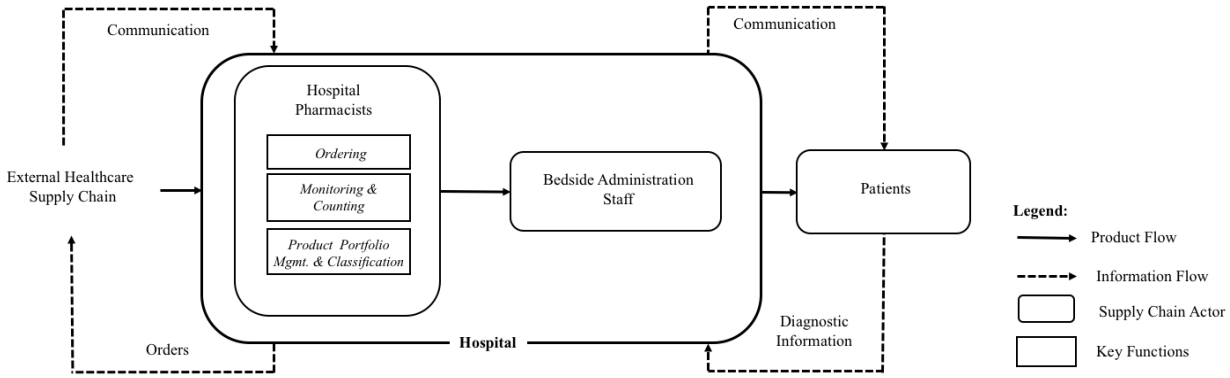

Figure 2.7 - A visual representation of the hospital and its core inventory management functions.

Furthermore, this chapter will present and contextualise literature regarding these pivotal functions of inventory management at tertiary hospitals and investigate how strategies in these inventory management disciplines can be used to prevent stock outs at hospitals.

2.3.3.1 Product Portfolio Management and Classification

The product portfolio managed at the hospital is determined by the formulary used. A formulary is a policy, containing a selection of medicines and treatment guidelines that are designed to facilitate rational and effective prescribing while controlling drug expenditures (Sutters, 1990). When deciding on the content of the formulary, common decision criteria include the safety, clinical efficiency and the cost effectiveness of the drug (Scroccaro, 2000). An example of how the cost-efficiency of the drug can be used in the selection is the case of new antibiotics entering the market. While they may be more effective than their substitutes, they are often only recommended for use when the patient does not respond to the older drug, as they are far more expensive (Ibid). Formularies can be implemented on a hospital, regional or a national level (Ibid). The national essential medicines list, which decides on what should be available for use in the public healthcare system, serves a similar role. In the management of health commodities, reducing the size of the product portfolio is known to facilitate inventory and information management and have a positive impact on both distribution and warehousing costs (USAID, 2011).

Healthcare items are not a homogenous group. Instead, it is made up of a large variety of products with different storage requirements, demand characteristics and economic values (Saha and Ray, 2019). In order to encompass all these different needs into the management of the healthcare supply chain without making the supply chain too complex to manage, items are often categorized into uniformly handled classes. Classifying healthcare products also serves the purpose of focusing hospitals' limited resources, ensuring a high output-to-input ratio (Vila-Parrish and Ivy, 2013).

A widely used method of classifying products in commercial supply chains is to group the stock-keeping units (SKUs) based on the pareto principle based on a specific criterion: a so-called ABC (*Always, Better Control) - classification.* The most common criterion for classification is the usage value of the SKU, but other criteria may also be used depending on the organisation's needs and objectives. In Table 2.4, the optimal inventory management strategy for each class in an ABC-classification based on usage value is presented.

Table 2.4: Inventory management strategies for healthcare commodities based on the ABC-classification, reprinted from Vila-Parrish and Ivy (2013).

Control Procedure	**A items: high consumption value**	**B items: moderate consumption value**	**C items: low consumption value**
Degree of safety stock	Very low or stockless strategy combined with frequent ordering	Low, ordering done on a less frequent basis	High, bulk ordering on an infrequent basis
Demand	Should be regularly occurring (e.g. daily)	Monthly	Quarterly
Material Planning	Accurate and updated regularly	Can rely on historical data	Estimates are sufficient
Optimisation Effort	High, focus on reducing waste, obsolescence and surplus	Moderate	Review policies annually
Number of Suppliers	High, short lead times required, centralized control	2-4 sources, shorter lead times preferred	1-2 sources, decentralized control

While usage value indeed is an important factor to consider, some argue that product classification in the healthcare system must take into account the consequence of possible stock outs on the patients' health. Therefore, several studies suggest complementing the ABC analysis with a VED (Vital, Essential, Desirable) analysis at secondary and tertiary hospitals (Kant et al., 2015; Kanyakam, 2018; Kumar and Chakravarty, 2015; Manhas et al., 2012). This is done by classifying medicines based on to what extent unavailability of the medicine affects the outcome of the patients' treatment (Kumar and Chakravarty, 2015). Based on the outcome of the combined ABC and VED analysis, the drugs are then placed into three categories, I, II and III, that each require a different level of attention (Kanyakam, 2018). In Figure 2.8, the logic behind the categorisation of a medicine is shown in a matrix, where the annual expenditures are displayed on the ABC axis, and the criticality of the stock outs is displayed on the VED axis.

Criticality	A	B	C
D	AD Category I	BD Category II	CD Category III
E	AE Category I	BE Category II	CE Category II
V	AV Category I	BV Category I	CV Category I

Volume

Figure 2.8 - An illustration of an ABC-VED classification matrix.

A study performed at a tertiary hospital in India showed that, when an ABC-VED analysis was used as a basis for item classification, only 21 percent of the SKUs belonged to the category requiring maximum attention (Kumar and Chakravarty, 2015). Research performed by Tabish et al. (2012) and Vaz et al. (2008) at other tertiary hospitals have shown similar results, with 18 percent and 23 percent respectively belonging to category I.

2.3.3.2 Ordering

When orders should be placed and in what quantities is systematised by the inventory policy used in the inventory management strategy. No inventory policy is a panacea for every supply chain. The result of the policy depends on the characteristics and capacity of the supply chain, the market where it operates and the overall objectives and goals that are being pursued.

Inventory policies commonly used in healthcare systems are min-max policies, where the order points and order quantifications are set to ensure that the inventory never falls below the minimum threshold nor raises above the maximum (USAID, 2011). In these systems, the order quantity is determined by calculating the difference between the inventory level at the time of order and the decided maximum inventory level (Ibid). These policies can be categorised into periodic-review policies and continuous-review policies based on when information regarding stock levels are collected and orders are placed.

- In periodic review policies, data on stock levels are collected and orders placed once every review period, while
- continuous-review policies on the other hand, make use of real time monitoring to keep track of stock levels and a predetermined minimum level of stock triggers a replenishment order (Rizkya et al., 2018).

The orders trigger replenishment distribution upstream in the supply chain which will be delivered following a lead time. All processes that need to be conducted before an order is fulfilled, e.g. order

processing, packing, delivering and receiving, are included in the lead time (Axsäter, 2006). Due to the lead time between order and delivery, the stock levels cannot solely be regarded as the physical stock available at the warehouse. As backorders from suppliers constitute debts of stock to the customers and outstanding orders to suppliers constitute receivables from suppliers, they too must be included in the stock level calculations. Typical stock measures in inventory policies include inventory position (physical stock level + outstanding orders - backorders) and inventory level (physical stock level - backorders).

Periodic-review policies and continuous-review policies place different prerequisites on the supply chain and yield different results. According to Rizkya et al. (2018), continuous-review policies are costly to implement and the need for real time data collection places high demand on the stock-keeping facilities' monitoring capacity. However, they are better suited for high-demand situations when the supplier is not able to deliver the requested order quantities (Rizkya et al., 2018). Axsäter (2006) concur with Rizkya et al. on this and adds that continuous-review policies reduce the need for safety stock as compared to periodic-review policies, as the reorder point does not have to guard for demand fluctuations during the review period.

Periodic-review policies, on the other hand, are easier and less costly to implement and do not require the same level of monitoring capabilities as their continuous-review counterparts (Axsäter 2006). Adding to this, following a periodic-review policy facilitates the coordination and trunking of orders, resulting in lower transportation and order costs due to economies of scale (Axsäter 2006). When opting for a periodic review policy, the review period should be based upon the inventory's level of demand fluctuation together with the costs of holding, delivering and ordering stock (Moons et al., 2019). A short review period renders the policy similar to a continuous review, while a longer review period may reduce costs at the expense of making the system less responsive (Axsäter 2006).

In healthcare systems, stock keeping actors typically follow a mix of periodic and continuous review policies in which the replenishment criteria jointly decided for groups of products (Gebicki et al., 2013). As storage capacity typically is limited throughout the healthcare system (Bijvank and Vis, 2012), Maestre et al. (2018) stress that storage capacity should be included as a balance constraint.

In every system under uncertainty, the configuration of the reorder system constitutes a balance between the risk of a stock out occurring and the capacity strain and cost of holding high levels of stock. High reorder points imply large safety stocks, defined as the minimum stock-level before a replenishment order is placed with the addition to the lead time of replenishment (Monk and Wagner, 2013). The quantity in which replenishments also have to be balanced, as high quantities incur increased holding costs while low quantities increase order and distribution costs, as orders have to be placed more frequently (Axsäter 2006). Axsäter (2016) maintains that reducing the risk of stock outs requires an exponential increase in safety stock levels, making ensuring absolute availability extremely costly. Nonetheless, since stockouts in the pharmaceutical supply chain are deemed unacceptable due to their severe implications, carrying exceedingly high levels of safety stock to secure availability is a common strategy (Uthayakumar and Priyan, 2013; Vila-Parrish and Ivy, 2013). This strategy, while effective in preventing stock outs, requires sufficient storage capacity, and the elevated inventory holding costs risk starving other parts of the organisation of financial resources (Maestre et al., 2018).

Machado Guimarães et al. (2013) mention that pharmacists at the hospitals also employ other strategies to avoid stock outs. For example, order quantities can be inflated to ensure that inventory levels will be sufficient. This is especially common in instances where orders are often not delivered in full quantity (Ibid.). Order inflation has been shown to lead to bullwhip effects (Houlihan, 1985). This phenomenon is referred to as the Houlihan effect. According to Campuzano and Mula (2011, p.27) this "*implies more demand in the production system, which inevitably leads to more unsatisfactory deliveries*". Bullwhip effects in healthcare supply chains are also found to be exacerbated by order batching by upstream distributors to profit from economies of scale (Machado Guimarães et al., 2013). This is referred to as the Burbidge effect (Ibid.). Campuzano and Mula (2011) argue that the Burbidge effect often can be attributed to the strive to optimise deliveries, and moreover suggest that the periodic resupply renders demand more variable in the upstream supply chain.

2.3.3.3 Monitoring and Counting

Monitoring of consumption, and counting of inventory are core supporting activities to the ordering function, but also for forecasting. This is because the most common forecasting technique used at hospitals is to determine the future demand through the analysis of historical consumption data (Rachmania and Basri 2013). The consumption data is then paired with observations of the stock level at the hospital to act as an input to the order system, deciding whether a replenishment order should be placed and in what quantities (Yadav, 2015). When there is an electronic logistic system in place, data is entered into the system continuously, with cross-referencing performed through physical stock-counts of the inventory.

Axäter (2006) suggests the counting should generally be performed more often for items that are high in demand, as stock levels change more rapidly for these items. Previously, periodic counting, where the entire inventory is counted with predetermined time intervals in between, has been the norm. However, as stated by Rossetti et al. (2001), cycle counting has been receiving increased attention as an alternative counting method in recent years.

What sets cycle counting apart from the traditional periodic counting is that only a selection of the total inventory is counted each time based on a predetermined criterion. By not counting the entire inventory every time, spikes in the workload can be flattened (Axsäter, 2006). According to Rossetti et al. (2001), common cycle counting methods include

- ABC-cycle counting,
- opportunity-based counting, and
- location-based cycle counting.

ABC-Cycle Counting

In ABC-cycle counting, the inventory is classified using the pareto principle. Commonly used selection criteria includes usage value, volume or order frequency. Items in the A-class, consisting of the items deemed most important for operations, are counted more frequently than the items belonging to a class of lower priority (Kök and Shang, 2014). By focusing resources on a prioritised class of items, counting efficiency can be increased.

Opportunity-Based Cycle Counting
Opportunity-based cycle counting does not make use of product classification to determine when a physical count of a specific item should be conducted. Instead, the counting of a SKU is initiated when an opportunity is presented, e.g. an order containing the SKU is received, or when the inventory level of the SKU drops below a predetermined point. Gumrukcu et al. (2008) suggest that this method can lead to substantial cost savings when used for high cost, slow moving items, but only result in insignificant savings for fast moving low-cost items that are high in demand.

Location-Based Cycle Counting
In location-based cycle counting, the warehouse is divided into zones that are counted systematically one at a time until the inventory in all zones has been checked, upon which the process is reiterated (Wijffels et al., 2016). Location based counting is a relatively simple method to use and implement, but as the selection criterion of the items in the count ignores product characteristics, it mainly serves to reduce time spent walking between the counted items and to distribute the workload more evenly (Gumrukcu et al., 2008).

2.4 Conceptual Framework

A challenge faced in obtaining a comprehensive understanding of the research scope was the large extent of the phenomena under investigation. Answering research question one and two necessitated an in-depth understanding of both the healthcare supply chain context in Zambia as well as their healthcare supply chain strategies. Answering research question two called for an understanding of how inventory management strategies employed at Zambian tertiary hospitals could remediate stock outs. The large scope of the study naturally raised the discussion about how the analysis should integrate aspects pertaining to the healthcare supply chain context, and aspects relating to supply chain strategies in a common model. As a means to guide the empirical data collection and analysis, it was seen as imperative that the findings from the frame of reference could be compiled within a comprehensive taxonomy for both stock out causes and inventory management strategies. Therefore, the conceptual framework illustrated in Figure 2.9 was produced.

In the framework, research question one focuses on how aspects of the healthcare supply chain context and healthcare supply chain strategies work towards achieving antibiotic availability. Correspondingly, antibiotic stock outs can be traced to shortcomings belonging to one or both of these two categories. Research question two focuses on the inventory management strategies that can be used to address stock outs. As is indicated in the model, inventory management strategies were analysed by considering four key inventory management functions: ‘product portfolio management and product classification’, ‘ordering’, and ‘monitoring and counting’.

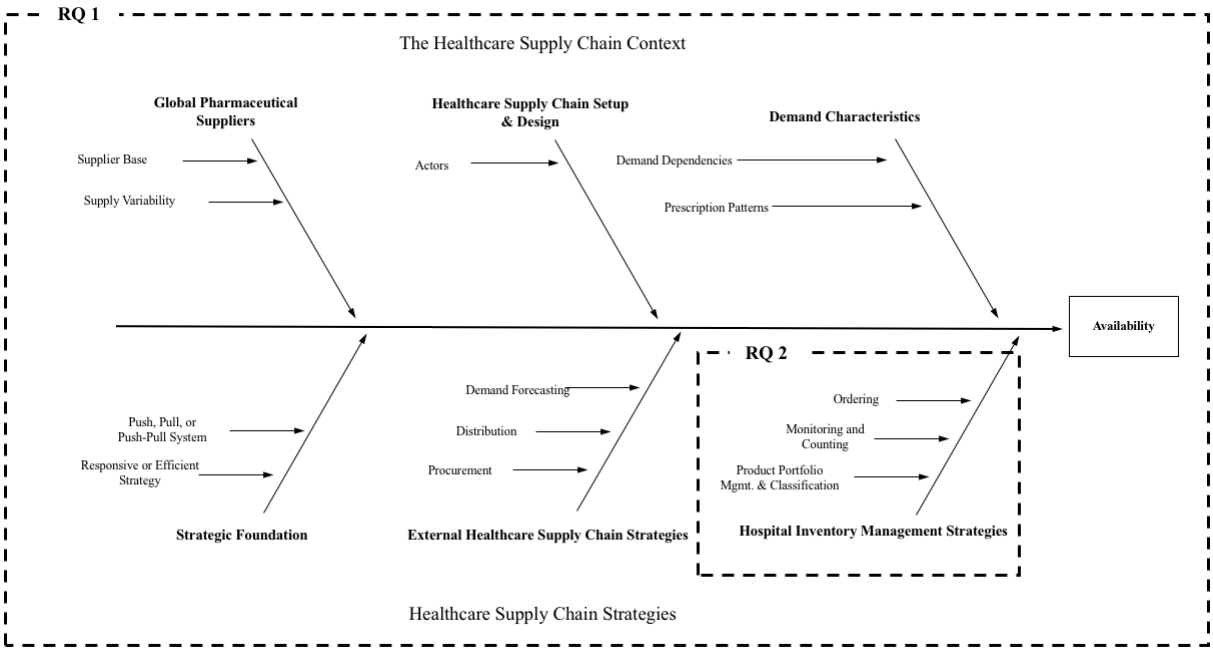

Figure 2.9 - The conceptual framework used to guide the empirical data collection and analysis to answering the research questions.

3. Methodology

In the methodology, the methods used to conduct research for this study are presented. The section is divided into four sections, outlining the research strategy, research design, methods used for the empirical data collection, and the credibility of the research.

3.1 Research Strategy

There are a multitude of alternatives with regard to how research can be conducted, and the suitability of any given method depends on the context (Farrelly, 2013). Farrelly (2013) suggests that a popular and effective approach to conduct research in the healthcare context, is through case studies. Farrelly (2013 p.95) furthermore adds that "*the 'case' can be an individual, ward, unit, hospital, or country".* In literature, the case study as a research method is sometimes illustrated as a form of triangulation, whereby empirical data collected by means of, for example, interviews, observation, and/or official documents is synthesised with existing theory to build a theory for the case, (and phenomenon), under investigation (Dooley, 2002; Eisenhardt and Graebner, 2007; Ridder, 2017).

(Ridder, 2017) and Farrelly support the notion of single-case research as an effective method for probing deeper into the causes of a complex phenomenon, and that the method is suitable for answering '*why'* and '*how'* a particular phenomenon occurs (Ridder, 2017). In light of this suggested suitability for healthcare contexts, we deemed case research as a meaningful method to consider for this particular study. Case studies are also assessed to be suitable for conducting research in research areas with a large number of constructs embedded in the phenomenon under investigation (Henry and Foss, 2015). This is undoubtedly the case for supply chain phenomena. In fact, both Eisenhardt (1989) and Yin (2014) are proponents of this approach, and Kotzab et al. (2005 p.268) emphasises that "*[case methodology] is particularly relevant for research into supply chains because it can help gather better information about the realities of supply chains and develop better, more complete theories about them*". This suggests that case research is not only a suitable method for conducting research in the healthcare context, but evidently so in the healthcare supply chain context too. In light of this, and in order to address the research questions that the study has set out to answer, the research was conducted by means of a case study. This choice of research method is supported more thoroughly below.

3.1.1 Case Research

Yin (2014 p.18) mentions that conducting research by means of a case study is particularly suitable when "*the boundaries between phenomenon and context are not clearly evident*". As is established in the frame of reference, stock outs can be attributed to a broad diversity of shortcomings at various stages in the healthcare supply chain. Furthermore, it is evident that the causes behind stock outs are difficult to isolate from the healthcare supply chain context.

Considering that actors of the healthcare supply chain are invariably at interplay, a root-cause analysis of antibiotic stock outs calls for an investigation of the entire healthcare supply chain context. In this regard, literature supports the use of case study as a research method. In fact, Henry and Foss (2015) suggest that

case study is a particularly suitable approach to accommodate for a large number of interconnected variables. This supports the selection of case research as research strategy for this particular study; while the effects of the investigated phenomena (stock outs) is topically limited to tertiary hospitals, causes are likely to be associated with the external healthcare supply chain in Zambia too. In order to answer research question one, the case investigated must therefore encompass the Zambian healthcare supply chain as a whole. This means that the empirical study must aggregate data from sources providing insights to the healthcare supply chain context in Zambia.

Considering the extensive scope of the phenomenon to be investigated, and considering the resource and time limitations imposed on the study, a single-case study was seen as the most appropriate course of action. This decision was furthermore supported by the fact that the upsurge of the Covid-19 pandemic during the spring of 2021 limited the possibility to obtain qualitative data on location.

3.2 Research Design

After having established the research strategy, the next course of action was to determine the research design. The research design determined how the collected empirical data collected in the single case study were linked to the research questions posed in the initial phase of the study (Bennett et al., 1994). In other words, the research design illustrates the rationale behind research activities.

3.2.1 Units of Analysis

An initial step in establishing the research design is defining the units of analysis for the study (Grünbaum, 2007; Tetnowski, 2015). Both Tetnowski (2015) and Yin (2014) posit that the research questions should guide the process of defining the units of analysis. Tetnowski (2015) furthermore points out that the units of analysis guide the selection of case units and units of observation.

In order to ensure that the units of analysis provided sufficient evidence to address the research questions, we revisited the research questions once more: ‘why do stock outs occur at tertiary hospitals in Zambia?’ and ‘how can stock outs of antibiotics at tertiary hospitals be addressed through inventory management strategy?’. As previously stated, the first research question seeks to explain the causal relationship between stock outs and supply chain shortcomings, while the second research question seeks to generate hypotheses for how stock outs can be addressed. This implies that the first research question is explanatory in nature, whereas the second research question is exploratory (Stebbins, 2001; Zainal, 2007). Considering that building a substantive theory is a key component of qualitative research, this has implications on the research design (Davis and McCarthy, 2005). For example, the necessity for internal validity is higher for explanatory research than it is for exploratory research (Stebbins, 2001; Yin, 2014). This makes the case for considering a wider array of sources to build substantive evidence to address research question one specifically.

The research questions also study different levels of entities; research question one regards the complete Zambian healthcare supply chain leading to tertiary hospitals, and research question two investigates

practices at tertiary hospitals in Zambia. This is also illustrated in the conceptual framework for the analysis. Bennett et al. (1994) describe that the entities investigated suggest the appropriate units of analysis. In light of this, the external healthcare supply chain and tertiary hospitals were selected as units of analysis suitable for addressing research question one. For addressing research question two, tertiary hospitals served as an appropriate unit of analysis.

Since the units of analysis for the two research questions share tertiary hospitals as a common element, the overall case study includes two units of analysis, namely tertiary hospitals and the Zambian external healthcare supply chain leading to tertiary hospitals. This means that the single-case is embedded (Runeson and Höst, 2008). An embedded single-case study signifies that the case encompasses multiple units of analysis, as opposed to a holistic single-case study, where the case comprises the unit of analysis (Tetnowski, 2015; Bass et al., 2018). Bass et al. (2018) underline that the embedded single-case study is advisable for exploratory research questions, and particularly useful for addressing explanatory research questions, further making the case for the choice of case design. These two models for single-case studies are juxtaposed in Figure 3.1.

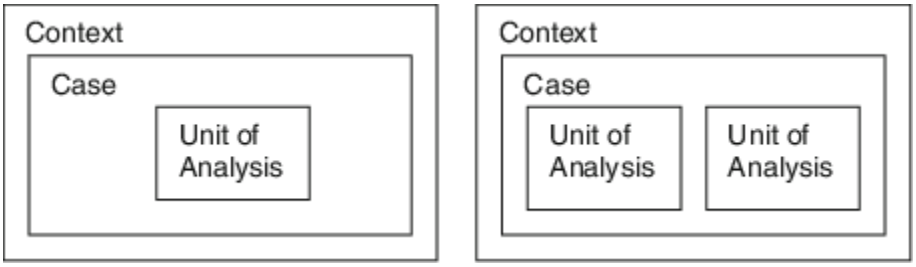

Figure 3.1: An exhibit of a holistic single-case study versus an embedded single-case study, reprinted from (Runesson and Höst, 2008).

It is also worth considering to what extent the selected units of analysis support the representability and relevance of results. While some of the results could potentially be extrapolated to healthcare supply chains in other LMICs, the scope of the case study is congruent with the scope of the study in general. This serves to say the study can be considered an intrinsic case study, whereby findings specific to the case were also the immediate focus of the study in general (Zainal, 2007). In Figure 3.1, this would be illustrated by the context and case being coextensive. We assessed that this suited the aim well and furthermore allowed for more substantial contributions to practice in the Zambian healthcare supply chain. Tetnowski (2015 p.40) indicates that evidence from qualitative research can *"allow for practical application to the population that the case most closely represents"*. In this study, this was tantamount to the Zambian healthcare supply chain in general.

3.2.2 Units of Observation

After having established the units of analysis, the next step is to define suitable units of observation. The units of observation, as the name suggests, are items or informants through which the researcher observes or measures the units of analysis (Blackstone, 2012; DeCarlo, 2019). In other words, the unit of observation is the entity from which empirical evidence is obtained (Piekkari and Welch, 2012).

In this study, we assessed that appropriate units of observation were informants and secondary sources that would provide evidence to comprehensively understand the units of analysis, and correspondingly, address the research questions. In order to achieve this, the units of observation were sampled through theoretical or purposive sampling. In purposive sampling, units are chosen purposely, based on their ability to provide insight to the study, (rather than by *solely* considering the representativeness of the units to the population they aim to reflect) (Eisenhardt and Graebner, 2007). Units of observation were therefore selected on the basis that they were considered to provide insights or give accounts of experiences that could support inductive theory development about the units of analysis (Eisenhardt and Graebner, 2007; Randall and Mello, 2012).

We instituted the sampling of units of observation in continuous dialogue with colleagues from ReAct Africa, who have dealt closely with actors across the Zambian healthcare supply chain, (inter alia clinical staff and pharmacists at Zambian hospitals, ZAMMSA, the MoH, as well as representatives of GHIs). Suitable units of observation were selected on the recommendation of the director of ReAct Africa, who had a deep understanding of the Zambian healthcare supply chain context and extensive experience in health system strengthening and pharmaceutical supply chain management. The selected units of observation are outlined in Table 3.1. The table also illustrates the connection between the respective research question, the unit of analysis used to address the research question, and the unit of observation through which empirical data will be collected. Nota bene, 'tertiary hospitals' as a unit of analysis was relevant for both research question one and two. As were the units of observation 'tertiary hospitals' and 'secondary sources'.

Table 3.1 - The units of analysis and observation for the study, adapted from (DeCarlo, 2019).

Research Question	Unit of Analysis	Unit of Observation
RQ 1	The external healthcare supply chain in Zambia	Informants from ZAMMSA and secondary data sources
	Tertiary hospitals in Zambia	Informants from tertiary hospital pharmacies and secondary data sources
RQ 2	Tertiary hospitals in Zambia	Informants from tertiary hospital pharmacies and secondary data sources

3.3 Empirical Data Collection

The embedded single-case study was conducted by means of several data collection methods. As is clarified in the research strategy, conclusions were drawn from the triangulation of findings from several data sources. Inlight of the units of observation detailed in the previous section, we performed a secondary data study of case-specific literature in addition to conducting interviews with informants from ZAMMSA and tertiary hospital pharmacies.

The research process for the empirical data collection is outlined in Figure 3.2.

Figure 3.2: The research process for the empirical data collection.

3.3.1 Secondary Data Study

A secondary data study, or literature review of case-specific research and grey literature, is a useful approach to understand the units of analysis (Rabinovich and Cheon, 2011). Furthermore, a secondary data study provides a backdrop of previous case-specific research, providing researchers with valuable insights as well as ensuring that new research does not simply duplicate previous studies (Höst et. al., 2006). This gives a hint at a suitable sequencing for the data collection; evidence retrieved from secondary data can inform the interviews. We therefore conducted the secondary study as an initial step in the empirical data collection, exposing any gaps in knowledge that could be addressed in the interviews.

The secondary data study was conducted by means of a literature review of previous literature on the units of analysis. The main body of the literature used for the frame of reference was composed of published articles and books found on the databases Google Scholar and LUBsearch. On the other hand, the secondary data collection in the single-case study primarily obtained evidence from grey literature, i.e. literature that has not been formally published in academic journals (Ridley, 2012).

The first step in the literature review consisted of mapping the previous research conducted about the availability of essential medicines in the Zambian healthcare system. Since the Zambian healthcare supply chain has been undergoing significant changes over the past few years, we found that a large share of the available body of literature on the topic was obsolete and not applicable to the current state of the units of analysis. As a consequence, the lion’s share of the secondary data used in the empirical data study was collected from grey literature, i.e. literature that has not been formally published in academic journals. This data consisted of, inter alia, government and ministry sources, and reports published by USAID.

An important aspect to mention with regard to the grey literature reviewed in the secondary data study, we recognised that the Zambian procurement function was referred to by different names. Since their establishment in 2021, ZAMMSA have been responsible for the procurement function in the Zambian healthcare supply chain which previously lied under the mandate of the MoH. Some of the information collected from secondary data sources is based on how procurement was performed while being under jurisdiction of the MoH. To the best of our understanding, the change was mainly one of change in governance structure rather than one of strategy and operations, which is also strengthened by governmental publications (MoH, 2017), (Zambia Medicines and Medical Supplies Agency Act, 2019). This led us to believe that recent literature regarding procurement under the MoH was representative of

how the function was managed under ZAMMSA. In light of this, the actor performing the central procurement will throughout this paper be referred to as ZAMMSA.

We collected secondary data mainly by means of keyword searching. Keywords were chosen based on their perceived relevance to provide evidence to build theory about the units of analysis. Queries frequently included reference to stock outs in Zambia, the healthcare supply chain context in Zambia, and healthcare supply chain strategies in Zambia. If queries generated poor results, they were generally reformulated through parallel reformulation or multi-tasking reformulation. Parallel reformulation entails a modification of search queries, altering some elements of the query while still targeting the same topic (Du and Evans, 2011). Multi-tasking reformulation entails deconstructing a complex query and reformulating it into simpler topics that are thereafter searched separately (Ibid). As suggested by Hinde and Spackman (2014), keyword searching was complemented with forward and backward citation searching, starting from articles that were considered particularly insightful.

3.3.2 Interviews

After performing the secondary data study, interviews were conducted with informants from the units of observation. Interviews as a qualitative method to conduct qualitative research is widely supported in literature (Eisenhardt and Graebner, 2007; Gammelgaard and Flint, 2012; Denscombe, 2017). For example, Eisenhardt and Graebner (2007 p.25) suggest that interviews are suitable for studying strategic phenomena, as well as an efficient way "*to gather rich, empirical data*". They furthermore add that this is a particularly efficient approach to study a phenomenon that is episodic and non-constant, which is largely the case for stock outs of essential medicines as well as inventory management practices (Eisenhardt and Graebner, 2007). Similarly, Denscombe (2017) suggests that interviews are well suited for gathering information about problems that are complex and abstruse in nature, and are well-founded in contexts subject to a high degree of change, as active informants can efficiently provide updated information. This made interviews not only an effective approach, but also efficient in measuring the units of analysis in this particular study. The efficiency benefits of interviews were also considered to be a key advantage of this method, considering the time and resource limitations as well as the limits imposed by the covid-19 pandemic.

In light of the units of observation defined for the study, we sought to interview informants with experience from practice at ZAMMSA and tertiary hospital pharmacies. This approach is supported by (Gammelgaard and Flint, 2012 np.), who underline that *"connecting with actual practice is a very important line of inquiry in logistics and SCM*" (Ibid.). This raised the discussion about how informants should be sampled, as well as how many informants that should be sampled. With regard to the sampling of informants, Eisenhardt and Graebner (2007) suggests that samples are selected for theoretical reasons, on the basis that they will illuminate the investigated phenomenon Ibid.). Informants were also sampled with the objective of achieving sufficient homogeneity to make sure that any conclusions drawn from the findings would prove sufficiently representative (Maxwell, 2013).

With regard to the appropriate number of informants, literature suggests that sample size for qualitative data samples should be sufficiently large to present an understanding of the phenomenon studied, while sufficiently small to allow for a more deep-probing analysis (Sandelowski, 1995; Vasileiou et al., 2018).

Furthermore, Morse (1991) and Vasileiou et al. (2018), argue that sample size is contingent upon the representativeness and usefulness of the data sources. If approaching the question of sample size from a grounded theory perspective, data saturation is achieved as *"data no longer sparks new theoretical insights, nor reveals new properties of your core theoretical categories"* (Vasileiou et al., 2018 p.3).

We faced challenges with getting hold of a large number of informants for a sufficiently long interview time. These difficulties were partly compounded by the fact that Zambian hospitals experienced an upsurge of Covid-19 cases during the time of the study, leaving staff in the healthcare system unavailable for long interviews. In light of the challenges faced with conducting qualitative research during the Covid-19 pandemic, as well as the time and resource limitations imposed on the researchers, we aspired to collect primary and secondary data that combined would prove sufficiently insightful to achieve data saturation for the study. Due to the resourcing of the study, we only conducted five in-depth interviews. Seeing that this number fell behind the suggested minimum number of informants required by for example (Bertaux, 1981) to reach data saturation, we found it advisable to complement and verify primary data with evidence retrieved from secondary data sources. We also cross-referenced findings with the hosting organisation ReAct.

In order to effectively utilise the network of the hosting organisation, informants were selected on the recommendation and assistance of the director of ReAct Africa. Suitable informants were chosen based on the research questions, units of analysis, and units of observation defined for the study. It was decided that suitable informants to interview consisted of two informants from ZAMMSA, one informant from ReAct (providing insights from the perspective of a cooperation partner to ZAMMSA and tertiary hospitals), in addition to two informants from two tertiary hospital pharmacies respectively. The informants, their positions, and the key perspectives they provide to the research area are outlined in Table 3.2.

Table 3.2 - A compilation of the interviewed informants.

Unit of Observation	**Interviewee**	**Position**	**Key Perspectives**
Informants from ZAMMSA	Informant 1	Director of Pharmaceutical Standards and Procurement at ZAMMSA	The external healthcare supply chain, particularly procurement; aspects pertaining to the global pharmaceutical supply chain; healthcare supply chain setup and design, particularly the administrative structure and financial flows; regulatory aspects and forecasting
Informants from ZAMMSA	Informant 2	Director of Logistics at ZAMMSA	The strategic foundation; the external healthcare supply chain, particularly distribution; healthcare supply chain setup and design aspects, particularly the administrative structure, and material and financial flows; transactions between ZAMMSA and tertiary hospitals
Informants from ZAMMSA	Informant 3	Projects Officer at ReAct (cooperation partner to ZAMMSA and tertiary hospitals)	The external healthcare supply chain; healthcare supply chain setup and design aspects, particularly the administrative structure; transactions between ZAMMSA and tertiary hospitals; demand characteristics, particularly pertaining to antibiotic demand; supply chain coordination with other

			disease-specific programs
Informants from tertiary hospital pharmacies	Informant 4	Pharmacist at University Teaching Hospital	Hospital inventory management strategies; demand characteristics; transactions between ZAMMSA and tertiary hospitals
Informants from tertiary hospital pharmacies	Informant 5	Pharmacist at Ndola Teaching Hospital	Hospital inventory management strategies; demand characteristics; transactions between ZAMMSA and tertiary hospitals

In order to collect evidence that would prove representative, the hosting organisation recommended that informants from tertiary hospitals were represented by a pharmacist from the University Teaching Hospital in Lusaka and the Ndola Teaching Hospital respectively. The rationale behind this selection was that the University Teaching Hospital was located in much closer proximity to the central warehouse than Ndola Teaching, and that they could potentially provide different perspectives of inventory management at tertiary hospitals. By studying tertiary hospitals labouring under different conditions, any conflicting statements versus agreement would hint at the possible generalisability of the evidence provided. Any generalisation could thereafter be verified in secondary data to the greatest extent possible.

As a research method, interviews are used to access primary information and expertise from the interviewee. Since the healthcare supply chain has been subject to recent reforms, and due to the fact that the study seeks to identify previously undefined factors, i.e. causes of stock outs, we developed an interview method that was both adaptable and flexible. 'Adaptable' refers to the characteristic that interview questions are easily tailored to the perspectives of the informant interviewed. 'Flexible' refers to the feature that the interviewer can deviate from the interview guide to ask follow up questions or bring up new topics to the discussion with the informant (Denscombe, 2017). This raised the discussion of whether to follow an unstructured or semi-structured interview approach. While semi-structured interviews provide the interviewer with support in form of an interview guide, an unstructured approach places higher demands on the interviewer's knowledge in the area (Ibid.). For the purpose of this study, and considering our limited experience of interviewing, a semi-structured interview format was deemed the most suitable.

The interviews were conducted with the aid of interview guides, accessible in the appendix. In light of the fact that interviewees were engaged in curbing the upsurge of covid-19 cases at the time of the interviews, the interviews were limited to one hour per interview. This was deemed to be sufficiently long for the purpose of the interviews; a view shared by the hosting organisation, the research supervisors, as well as the authors. However, it was nonetheless considered to be important that the interview guides were kept sufficiently direct for questions calling for a descriptive answer, to still allow for elaborated answers to open-ended normative questions. Therefore, the interview guides intermingled close-ended questions with open-ended dittos. This approach is supported by literature (Halcomb and Davidson, 2006). The balance between open-ended and closed-ended questions also have implications on interview structure. In fact, Halcomb and Davidson (2006) suggests that direct close-ended questions typically provide structure to the interviews, with the natural weakness that interviewees are compelled to choose from a finite set of prearranged responses. On the other hand, open-ended questions will likely entail richer and more normative qualitative data (Ibid.). Considering the objective that interviews remained semi-structured, we

opted for an approach where open-ended questions were combined with close-ended follow-up questions whenever it was deemed appropriate.

3.4 Data Analysis

Data analysis was guided by the conceptual framework presented in the frame of reference, reiterated in Figure 3.3 for the reader's convenience. In order to address the research questions, the collected empirical data was categorized into the categories defined in the framework. The analysis was thereafter structured around the research questions; the first part of the analysis was devoted to research question one, and the second to research question two. As is illustrated in the conceptual framework, the scope of research question one encompassed all the themes covered in the frame of reference. As such, the format of the first part of the analysis therefore largely mirrored that of the frame of reference. The second research question guided the second part of the analysis, where we sought to generate hypotheses as to how inventory management strategies at the hospital could address antibiotic stock outs. When addressing research question one, we compared empirical findings with the findings in the frame of reference to build theory that could explain the causes of stock outs. When addressing research question two, we analysed our empirical findings for tertiary hospitals in conjunction with the inventory management strategies outlined in the frame of reference.

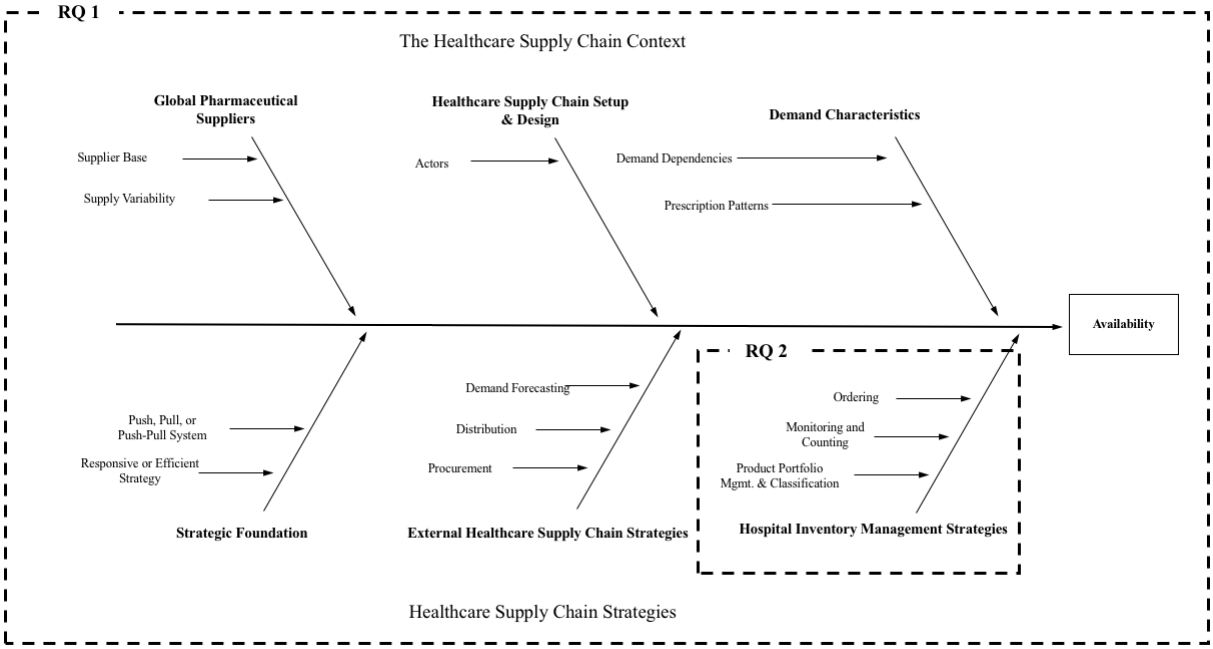

Figure 3,3 - Reiteration of the conceptual framework used to guide the empirical data collection and analysis to answering the research questions.

As mentioned, the collected secondary data and interview data was categorised into the thematic areas illustrated in the conceptual framework. This was straightforward for the secondary data, since the retrieved data was usually already placed in a context, guiding the thematic categorisation. However, the

interview data called for a more structured approach. The thematic analysis had to be preceded by a crude analysis of raw data. The raw data was composed of audio recordings, (all of the informants consented to the interviews being audio recorded). After the interviews, the audio recordings were transcribed word for word, producing what is referred to as a *verbatim transcription* (Halcomb and Davidson, 2006). For the crude data analysis of the interview transcriptions, the method proposed by Halcomb and Davidson (2006) was used in conjunction with Nasheeda et al.'s (2019) method for content analysis. The adapted method is illustrated in Figure 3.4, outlining key steps in how crude analysis of the interview data was conducted.

1. Audio recording and concurrent note taking.
2. Transcribing the audio-recorded interview.
3. Holistic-content reading.
4. Chronological plotting of key interview insights.
5. Thematic content analysis.

Figure 3.4 - Steps for conducting analysis of interview results, adapted from (Halcomb and Davidson, 2006) and (Nasheeda et al., 2019).

The content analysis was conducted manually through methods proposed by Nasheeda et al. (2019 p.1). These methods included holistic-content reading, as a means to *"familiarizing oneself with the transcripts"*, chronological plotting of key interview insights, and thematic content analysis, where interview data was categorised into thematic areas (Nasheeda et al. 2019). The holistic-content reading served as a way to tap into any potential narratives or linkages that could go lost in the process of segmentation. This course of action is supported by Maxwell (2012 p.237), who suggests that *"fracturing and categorizing your data can lead to the neglect of contextual relationships among these data"*. In the analysis of the primary data, we made sure to take note of any conflicting statements or testimonies indicating approval or agreement in facts. This was done as a measure to identify to what extent primary findings were sufficiently homogeneous to build theory that was valid and representative (Seidman, 2006). Conflicting statements were addressed through more meticulous triangulation with secondary data sources.

3.5 Credibility

The credibility of a study can be determined by considering to what extent the study is *reliable*, *valid* and *representative* (Höst et. al, 2006; Leung, 2015). A study is deemed *reliable* if the research could be repeated with the same results (Höst et. al, 2006; Leung, 2015). Moreover, a study is considered *representative* if the units of observation from which data is collected adequately reflects the population for which conclusions are to be drawn (Höst et. al, 2006; Leung, 2015). Findings are considered *valid* if the research method effectively measures what the study has set out to measure with accuracy (Höst et. al, 2006; Leung, 2015). An assessment of validity can also be approached by considering, as suggested by Maxwell (2012 p.216), "*how might your results and conclusions be wrong, and what are the plausible alternative interpretations and validity threats to these [conclusions]?"*.

With regard to the reliability of the study, this can be approached by considering to what extent the study could be replicated and still arrive at the same results (Höst et. al., 2006; Leung, 2015). This entails that the findings should be transferable to future studies with other participants than those who took part in the study in question (Korstjens and Moser, 2017). It also entails that findings can be confirmed by different researchers (Ibid.). Korstjens and Moser (2017 p.121) suggest that transferability can be achieved in interview studies by providing an extensive description of the context in which the informants labour, *"so that the behaviour and experiences become meaningful to an outsider".* Moreover, confirmability can be achieved by means of method transparency, detailing how the findings were collected and results generated (Shenton, 2004; Korstjens and Moser, 2017). We assess that the study conducted can be transferred, as a thorough description of the context in which the investigated phenomenon occurs is provided in the frame of reference, and in the empirical findings. Furthermore, we believe that the results could be confirmed. To enable scrutiny of the method and analytical process, we have provided a detailed description of the method used, exhibited the interview guides used for the primary data collection, and furthermore presented empirical data and analysis separately. The latter quality ensures that the reader with ease can separate the empirical findings from the hypotheses proposed by the authors.

With regard to representativeness of the study we will first consider the primary data specifically. We assessed that the evidence collected from ZAMMSA informants indicated a high degree of homogeneity, as informants provided similar answers to one another and voiced similar concerns. Analogously, this was also largely the case for the tertiary hospital informants. This was anticipated, considering that the study's scope was limited to tertiary hospitals for this particular reason. Furthermore, sampling of tertiary hospital pharmacy informants was conducted purposely, with the intent of achieving sufficient homogeneity to tap into experiences that would be representative of pharmacists at other tertiary hospitals in Zambia. With regard to homogeneity, Maxwell (2012 p.235) outline that *"a small sample that has been systematically selected for typicality and relative homogeneity provides far more confidence that the conclusions adequately represent the average members of the population than does a sample of the same size that incorporates substantial random or accidental variation".* To mitigate threats to the reliability of the primary data, we triangulated findings from the interviews with secondary data, and cross-referenced with the hosting organisation to avoid any misconceptions or influence of confounding variables.

In order to discuss the validity of the study, we deem it appropriate to revisit the research questions once again. The first research question seeks to explain a causal relationship, while the second research question generates hypotheses for how a phenomenon can be addressed, signifying that the questions are of an explanatory and exploratory nature respectively. Avis (2006) and Stebbins (2001) suggests that explanatory research necessitates a higher degree of internal validity than exploratory research. This gives credence to the research design; compared to research question two, the units of analysis investigated to address research question one included more informants, more secondary data sources, and considered a broader theoretical foundation established in the frame of reference. Addressing research question one therefore involved a more thorough triangulation of sources, minimising the effects of variables extraneous to the causal relationship that research question one investigated (Avis, 2006). Research question two employed a similar method, albeit with a more modest selection of primary and secondary sources.

Seidman (2006 p.24) claims that validity in primary data, more specifically interviews, can be achieved by cross-referencing between the data collected from separate primary sources; *"by interviewing a number of participants, we can connect their experiences and check the comments of one participant against those of others"*. This approach was integrated in the analysis of the primary data, and was seen as a meaningful way to ascertain that findings were valid, but also representative. Whenever these opinions coincided, we asserted that this was to some extent an indication of the fact that the information provided was representative, and could potentially be generalised (Ibid). Since we regarded the interview data too scarce to generalise solely based on primary data, we pursued external validity by verifying the primary data collected. This was performed by triangulating findings with secondary data sources.

While we do believe, to the best of our knowledge, that the insights provided by primary and secondary sources sufficed to establish reliable, representative, and valid conclusions, we wish to lend ourselves to discussing possible threats to reliance, representativeness and validity of the findings obtained from the interviews specifically.

The first caveat that we consider relevant to bring to the table is that we assessed that the Covid-19 pandemic greatly affected the method of the study, and may furthermore have affected the outcome of the study. Since interviews were conducted during a time when Covid-19 cases in Zambia were on the rise, we wish to call into question the external validity of the findings. We found that all of the informants interviewed voiced concerns about the added strain that the pandemic response had put on the healthcare supply chain. Likewise, most of the contemporary secondary data confirmed this position. As such, we highlight that some of the findings may not be reliable in the sense that they reflect the healthcare supply chain in Zambia in general, so much as they reflect the healthcare supply chain in Zambia *during the pandemic*. We addressed this by verifying findings from the primary data collection with evidence from pre-pandemic secondary data.

As a consequence of the Covid-19 pandemic, we also faced several challenges with regard to the resourcing of the study. The pandemic limited the possibilities of conducting qualitative research on the units of analysis, not only by inhibiting the possibilities of observing actual practice on site, but also possibly in terms of achieving data saturation in the *primary* data; due to the capacity strain that the Covid-19 response exerted on both ZAMMSA and the hospital pharmacies, we found that it was difficult to obtain a large sample of informants. This was addressed by conducting in-depth interviews, but also by means of verification of primary data using secondary data. Furthermore, in the analysis stage, results were cross-referenced with researchers at the hosting organization to ensure that the findings were authentic.

4. Empirical Data

In the fourth chapter, we compiled the empirical data acquired from the secondary data collection and interviews. The structure of the section was guided by the conceptual framework. Accordingly, both main sections, ‘the Zambian healthcare supply chain context’ and ‘healthcare supply chain strategies’, present evidence to explain the causes of stock outs. The last subsection of ‘healthcare supply chain strategies’, i.e. ‘hospital inventory management strategies’, also presents evidence that was used to generate hypotheses about how stock outs could be addressed using inventory management strategies.

The information presented was obtained solely from the secondary data study or interviews. If not otherwise stated, the information presented in this chapter was retrieved from interviews with informants representing ZAMMSA, and/or the investigated tertiary hospital pharmacies in Zambia.

4.1 The Zambian Healthcare Supply Chain Context

In the following section, the design of the Zambian public healthcare supply chain context is described. The section describes the global pharmaceutical suppliers, the healthcare supply chain setup and design, and the demand characteristics for antibiotics in Zambia. The empirical data presented in this section was used as evidence to answer research question one.

4.1.1 Global Pharmaceutical Suppliers

The data obtained in the interviews did not provide any evidence that attributed stock outs to global pharmaceutical suppliers. However, the secondary data collection shedded more light on the influence of global pharmaceutical suppliers. There is reason to believe that the global pharmaceutical suppliers from which antibiotics in Zambia are procured share similar characteristics with the global suppliers outlined in the frame of reference. This would mean that the Zambian supply chain labours under similar circumstances as their counterparts in other LMICs. This is partly supported by the fact that Zambia procures antibiotics from a small number of global pharmaceutical suppliers (Center for Global Development, 2021). This can be interpreted in light of the fact that Zambia has a weak local production and imports the large majority of their pharmaceutical supplies (MoH, 2017; MoH, 2019; Kachali et al., 2014).

In a report from 2019, the Center for Global Development claimed that there is little competition between global pharmaceutical suppliers from which Zambia procures antibiotics. This is outlined in Table 4.1, illustrating the Herfindahl-Hirschman index (HHI) for Zambia’s drug suppliers per therapeutic area. In the table, Zambia is compared to five other LMICs. The HHI indicates the competition between suppliers in an industry, and is calculated by summing the squared market share of the competing suppliers. A high HHI indicates that there is little competition between suppliers. The HHI for antibiotics in Zambia is 61.9 percent, and while this is less than for example the HHI for HIV antiretrovirals, it still implies that there is little supplier competition between antibiotic suppliers in Zambia (Center for Global Development, 2021). The report furthermore outlined that for procurers with a low HHI the price paid for pharmaceuticals was often lower, allowing for procurement of increased quantities (Ibid.).

Table 4.1 - Competing supplier's market share per therapeutic area for Zambia, in comparison with five other LMICs (including the state Kerala in India), reprinted from (Center for Global Development, 2021).

Area \ Country	Kerala	Philippines	Senegal	Serbia	SouthAfrica	Tunisia	Zambia
Anemia		66.4 %	100.0 %	88.1 %			
Antiulcerants	44.4 %	44.0 %	18.4 %	72.1 %	61.4 %	50.4 %	81.3 %
Antihypertensives	62.2 %	62.2 %	69.6 %	43.7 %	76.5 %	75.1 %	91.7 %
Antibiotics	21.9 %	51.9 %	88.3 %	63.2 %	29.0 %	44.5 %	61.9 %
Antiparasitics	33.1 %	100.0 %	40.0 %		91.8 %	97.5 %	98.2 %
Arthritis Immunosuppressants	37.4 %	57.5 %	31.3 %	57.9 %	61.6 %	63.1 %	90.6 %
Asthma / COPD	84.8 %	62.9 %	96.2 %	84.0 %	78.9 %	95.7 %	100.0 %
Cancer	90.6 %	61.7 %	76.0 %	58.8 %	65.0 %	64.4 %	100.0 %
Contraceptives hormones	84.4 %	97.2 %	87.3 %		72.5 %	80.7 %	98.7 %
Diabetes	27.3 %	51.5 %	72.4 %	61.0 %	59.8 %	56.0 %	100.0 %
HIV Antiretrovirals	64.7 %				82.2 %	84.4 %	100.0 %
Lipid regulators	74.1 %	46.7 %	46.4 %	59.8 %	81.2 %	70.3 %	98.8 %
Nervous system medications	89.1 %	78.2 %	100.0 %	78.2 %	83.3 %	91.4 %	99.5 %
Pain Analgesics		55.0 %	93.2 %	40.6 %	50.0 %	30.8 %	100.0 %
Tuberculosis	40.0 %	59.7 %	30.7 %	46.5 %	50.4 %	61.5 %	80.6 %
Vitamins and Minerals		99.0 %	88.0 %	97.7 %	99.8 %	26.6 %	

4.1.2 The Public Healthcare Supply Chain Setup and Design

The Zambian public healthcare supply chain revolves around its central warehouse located in Lusaka. Generally, healthcare commodities are distributed to the health facilities or their corresponding pharmacies via cross-docking hubs. However, there are two exceptions to this. For remote facilities, an additional tier is added to the system with staging posts supplied by cross-docking hubs. The staging posts act as intermediary storage holding points. Hospitals consuming a large volume of healthcare commodities, such as tertiary hospitals, have their corresponding pharmacies supplied directly by the central warehouse, without intermediary cross-docking or storage. A simplified version of the distribution network structure is presented in Figure 4.1. Before distribution, all replenishment orders from health facilities are processed individually. This means that commodities that are to be delivered are picked and packed individually for each facility at the central warehouse.

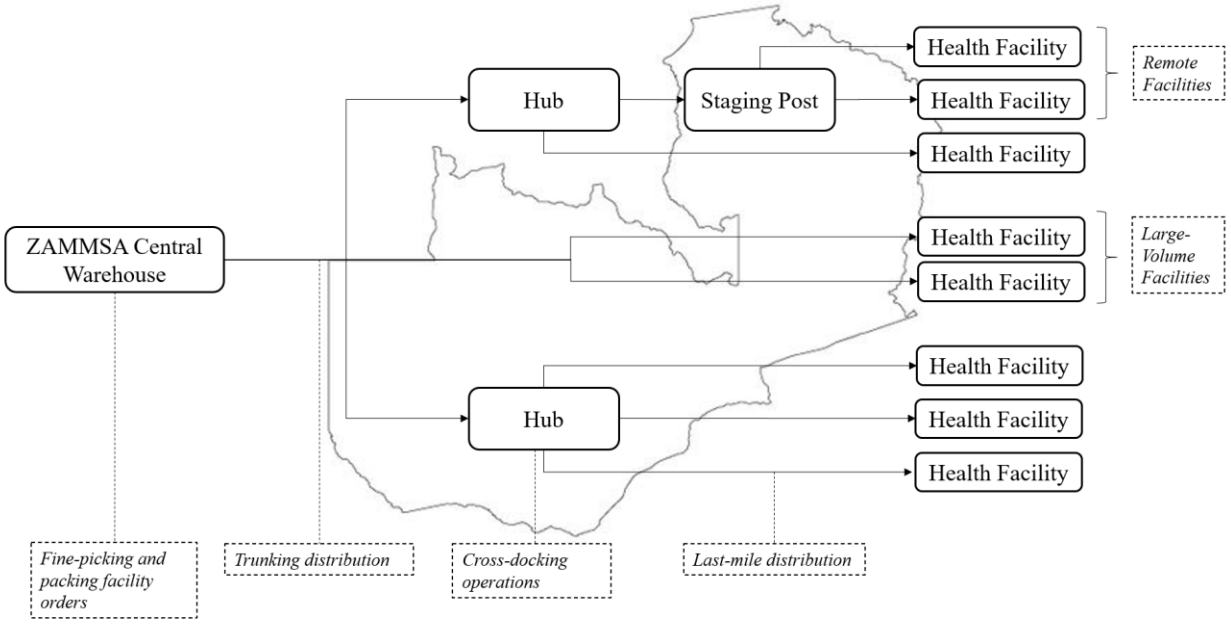

Figure 4.1 - A simplified version of the distribution network structure between the ZAMMSA Central Warehouse and healthcare facilities.

The cross-docking regional hubs were implemented as a part of the Government of Zambia's Essential Medicines Logistics Improvement Program (EMLIP), moving away from the previous system in which orders to the central warehouse were consolidated by intermediary stock-keeping facilities managed by the District Health Offices (DHOs). In this system, the last-mile distribution to facilities was under jurisdiction of the DHOs. The change entailed a reform of the distribution network structure and a centralisation of warehousing and order-processing functions. The change of design was implemented to improve the availability of medicines at health facilities and the last-mile distribution, which was considered a bottleneck at the time. After the completion of a randomised trial of two alternative supply chain models in which the cross-docking model was found to have the greatest impact on the prevalence and length of stock outs, it was decided that the model was to be implemented nationwide (World Bank Group, 2012). In the new structure, the distribution network comprises six cross-docking hubs in Chipata, Choma , Kasama, Kitwee, Lusaka Mongu, Kitwe, Kasama, Lusaka and Choma and seven staging posts in Chama, Kabompo, Livingstone, Mansa, Mkushi, Solwezi and Zambezi. The distribution mandates of the cross-docking hubs and staging posts are illustrated in Figure 4.2. Each colour-coded area represents the catchment area for a hub or staging post.

Figure 4.2: The distribution mandate of cross-docking hubs and staging posts in Zambia, reprinted from (Medical Stores Limited, 2013)

According to ZAMMSA informants, the centralisation of warehousing and order-processing functions rendered the capacity at the central warehouse insufficient. One of the ZAMMSA informants described the implications of the design change as follows:

> *"In early 2010, when this kind of processing [bulk shipments to DHOs] was done, we had less than 300 orders that were coming to ZAMMSA. (...) [After the change] the number of orders skyrocketed, and there are now about 2700 facilities placing orders to the central level. And when I say 2700 facilities, it's not just one order per facility. Commodities belong to four categories, and ZAMMSA receives ARV orders, essential medicine orders, orders for HIV test kits, and laboratory orders from most of these facilities. Therefore, the workload centrally soared."*

In the randomised trial serving as a basis for the implementation of the cross-docking design, the resupply interval was set to one month. However, the ZAMMSA informants explained that the lack of central ordering and distribution capacity to accommodate for the recent reform necessitated an increase of the resupply interval from one to two months, which is the interval currently used.

4.1.1.1 Healthcare Supply Chain Actors

In Zambia, the governmentally managed public healthcare maintains a strong position, with over 80 percent of patients seeking care in publicly managed health facilities (MoH, 2015b). The second largest healthcare provider in Zambia is the organisation network Churches Health Association of Zambia (CHAZ), managing a parallel, mostly independent healthcare supply chain with a direct distribution system between their central warehouse and hospitals (Axios International, Inc., 2017). While there are privately owned health facilities operating in Zambia, they account for a relatively small share of the service provided and have a limited outreach outside the urban areas (MoH, 2015b).

The MoH bears the overall responsibility for providing public healthcare in Zambia. However, their focus is mainly strategic and revolves around policy development, regulation and norm setting. Supporting the ministry in the regulation of the healthcare supply chain is the Zambia Medicine Regulatory Authority (ZAMRA), responsible the establishing, maintaining and enforcing standards concerning the *"quality, manufacture, importation, exportation, distribution and sale of medicines and allied substance"* (Medicines and Allied substances Act, 2013).

The operational aspects of the healthcare system supply chain are handled by ZAMMSA, a governmental agency responsible for the distribution, storage and procurement of medicines and medical supplies. In the distribution of health commodities in the Zambian healthcare supply chain, ZAMMSA work together with a third party logistic provider contracted through a tripartite deal negotiated with the The USAID Global Health Supply Chain Program-Procurement and Supply Management (GHSC-PSM) project acting as the third part. The third party logistics provider assists in handling the material flow between the ZAMMSA central warehouse and the regional hubs. The mandate of third-party logisticians also includes responding to and delivering emergency orders to healthcare facilities.

There are five different types of healthcare facilities in Zambia: health posts, health centres, first level hospitals, second level hospitals and tertiary hospitals. The patient referral structure between the health facilities is hierarchical, implying that tertiary hospitals receive referrals from second level hospitals, second level hospitals from first level hospitals, and so forth. The characteristics of the different types of health facilities are presented in Table 4.2 below.

Table 4.2 - Characteristics of healthcare facilities in Zambia, information retrieved from MoH (2013)

	Health Post	Health Centre	First Level Hospital	Second Level Hospital	Tertiary Hospital
Catchment Population	1,000 - 7,000	10,000 - 50,000	80,000 - 200,000	200,000 - 800,000	800,000+
Health Service Provided[2]	Basic first aid services	Medical, diagnostic, and obstetric services	Medical, diagnostic, obstetric and surgical services	Internal medicine, diagnostic, general surgery, paediatrics,	Internal medicine, diagnostic, surgery, paediatrics,

[2] The provided health services may vary between facilities in the same level of healthcare

				obstetrics and gynaecology, psychiatry and intensive care services	obstetrics, gynaecology, psychiatry, intensive care, training and research

The two hospitals investigated, Ndola Teaching Hospital (NTH) and the University Teaching Hospital (UTH), are both tertiary hospitals, providing specialised care and receiving referrals from hospitals belonging to a lower level of healthcare. NTH has 851 beds at their disposal (World Health Organization, 2021) while UTH has 1655 beds (University Teaching Hospital, Lusaka | ZUKHWA, 2021). The locations of the two hospitals are illustrated in Figure 4.3.

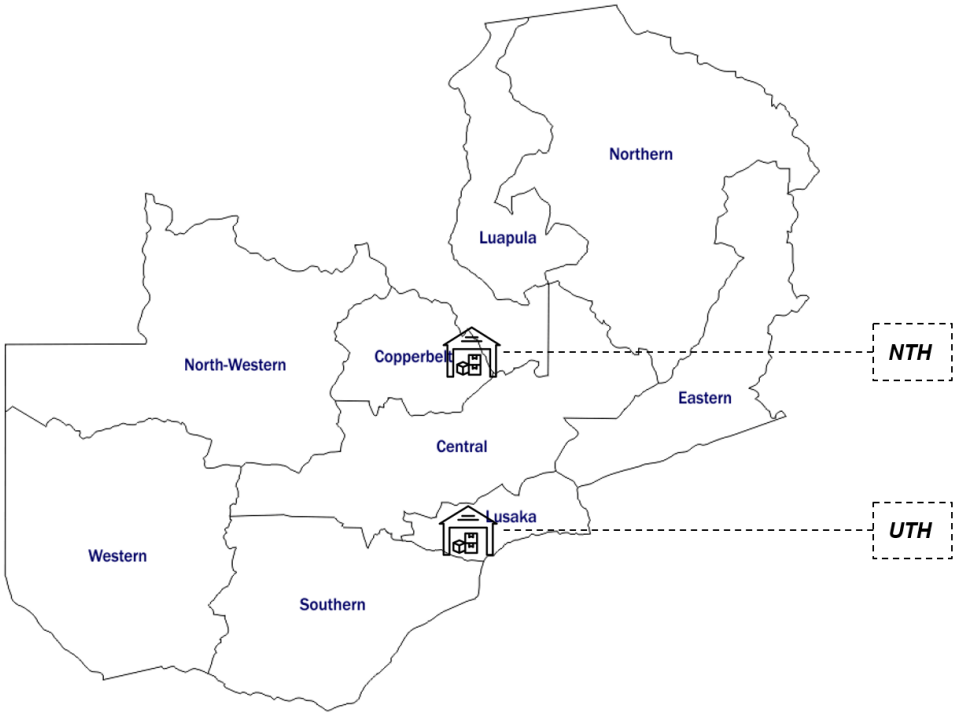

Figure 4.3 - The location of the two sampled hospitals, NTH and UTH

The Zambian healthcare supply chain is closely interconnected with the global health community and works in close collaboration with GHIs to battle diseases such as Tuberculosis (TB), HIV/AIDS and Malaria. The disease-specific organisational structure of the global health community also permeates the Zambian system, with statutory bodies such as the National HIV/AIDS/STI/TB Council (NAC) operating under the MoH.

The GHIs conduct their work through programs together with the statutory bodies to provide a coordinated response when combating their target diseases. The GHIs are centred around the management of specific healthcare commodities, and act somewhat autonomously from the general healthcare supply

chain in the sense that they perform their own demand forecasting, reporting and procurement. Orders are also placed individually for each GHI, and are later harmonised with ZAMMSA's distribution schedule to uniform the distribution of all items in the system. Adding to this, the GHIs also set their own independent targets for what they should achieve in terms of program reach and growth. Once commodities have been procured, they are taken to ZAMMSA for storage and distribution to target health facilities.

A visual representation of the Zambian healthcare supply chain leading up to tertiary hospitals is illustrated in Figure 4.4. The figure illustrates, in a simplified form, the actors involved in the supply chain, their roles, and the material and information flows between them.

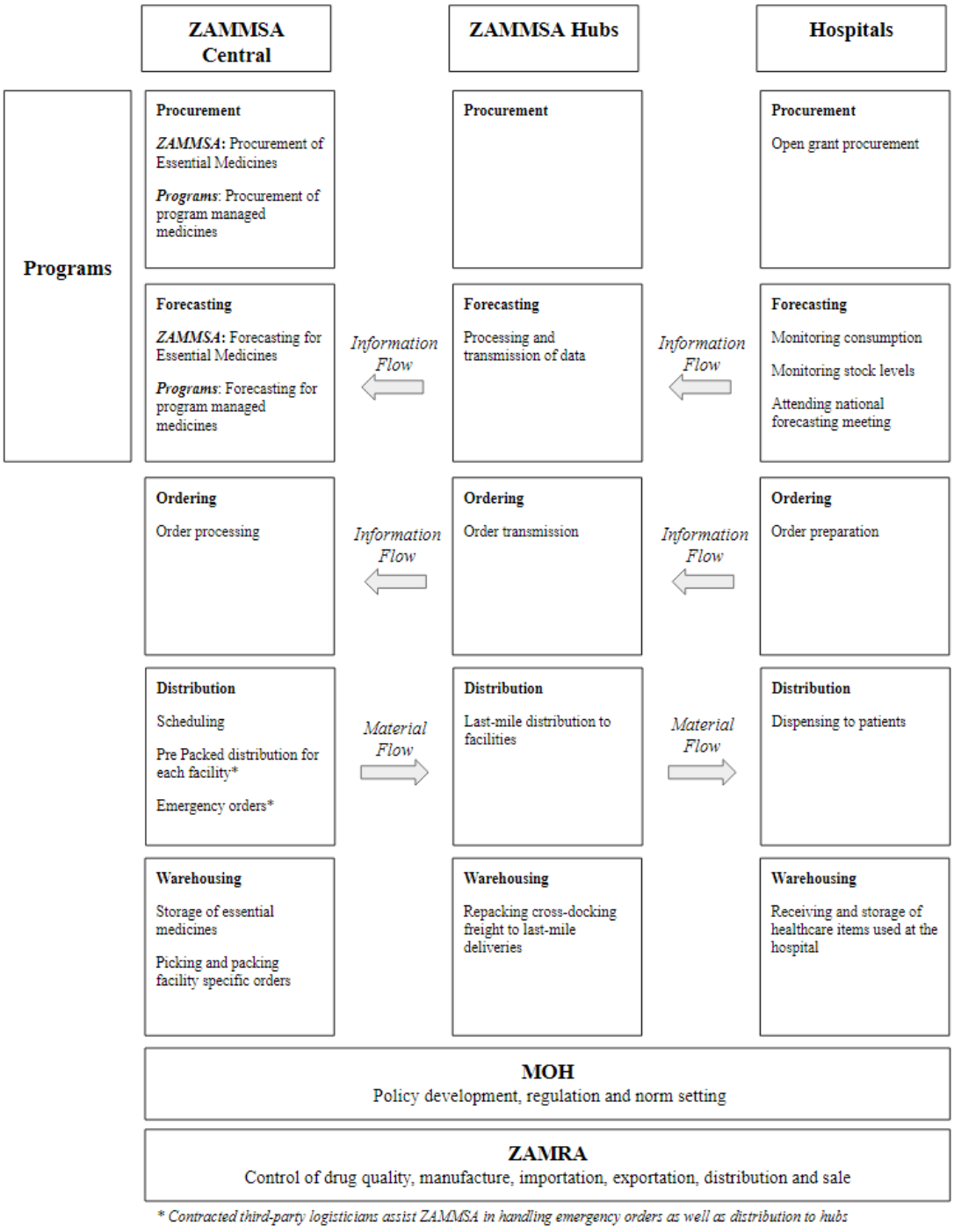

Figure 4.4 - A simplified mapping of the actors involved in the supply chain, their roles, and the material and information flows between them.

Despite a SWAp being implemented in the Zambian healthcare sector as early as in 1993, the MoH (2019) have expressed concern regarding the lack of coordination and accountability in the management of the healthcare supply chain. More specifically, deficient high-level coordination and information sharing between the MoH and its partner organisations in procurement, financing and forecasting (Ibid.).

Mwisongo et. al (2016 p.258) quotes an MoH officer in their study, commenting on how SWAp are being followed by GHIs in the country:

> *"SWAp is a very good structure that has been in place for many years now. However, these strong GHIs do not make use of it … Like we are here in this meeting preparing our annual plan but they are not participating."*

The allocation of available funds in the Zambian healthcare system has also been called into question. According to the Health Financing Strategy of 2017-2027 (MoH, 2017), about 50 percent of the expenditure for procurement of medicines is spent on drugs used for the treatment of HIV/AIDS or malaria, which by large is financed from external actors. The report claims that the allocation of funds to these diseases is disproportionate, and it furthermore suggests that earmarked funding for specific GHIs or medicines decrease the resilience of procurement to fill gaps in underfunded areas (MoH, 2015a; MoH, 2017).

The healthcare expenditures in Zambia are covered by funds from several sources. In a report from 2018, the MoH outlines that the vast majority of healthcare funding comes from the Zambian government in addition to donors (MoH, 2018). For example, in 2016, 38% of total health expenditures were funded by the government, and 43% were covered by donors (Ibid.). The remaining funds mainly came from out-of-pocket expenditures from Zambian households (12%), and medical insurance companies (9%) (Ibid.). This is illustrated in Figure 4.5. Several secondary data sources assert that the reliance on donors should raise concerns (MoH, 2017; Masiye and Chansa, 2019). In a report from 2019, Masiye and Chansa from the World Bank conclude that the *"overall health financing landscape [in Zambia] shows inadequate level of domestic health spending, heavy reliance on donor funding, fragmentation in financing sources, and limited pooling" (Masiye and Chansa, 2019 p.4)*. Furthermore, the vast majority of donor funding in Zambia was found to target specific healthcare responses, such as HIV/AIDS and STI programs (Ibid.). In fact, the funding earmarked for HIV/AIDS and STIs amounted to 70% of donor expenditures in 2015 and 2016 (MoH, 2018). Masiye and Chansa (2019 p. 18) also concluded that *"most donor funds are increasingly targeted at specific programs or regions"*, and that *"it is recommended that a framework of common planning be implemented to ensure that allocation of all health sector resources is harmonized"* (Masiye and Chansa, 2019 p. 18).

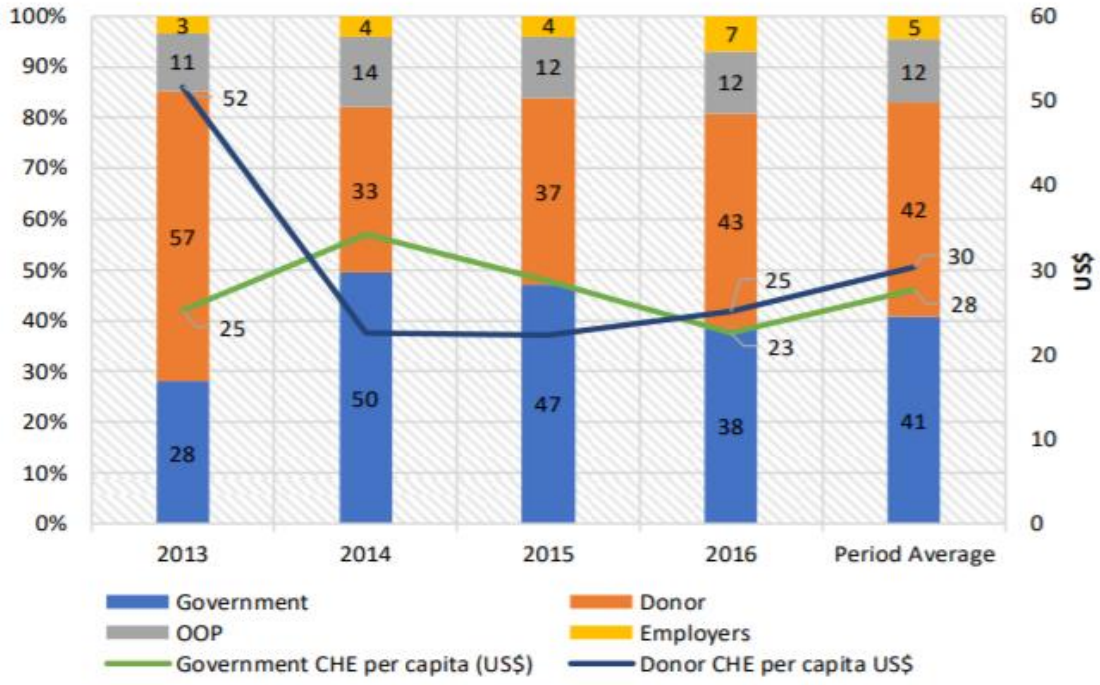

Figure 4.5 - Current health expenditures (CHE) between 2013 and 2016, segmented by sources of funds, reprinted from (MoH, 2018).

4.1.2 Demand Characteristics

The demand characteristics of health care commodities in Zambia are complex, and as suggested by previous research, affected by the physicians' prescription behaviours, the patients' particular response to the prescribed treatment, the disease panorama in the hospitals' catchment population areas and the demand dependencies between items.

Judging by the average monthly demand for antibiotics stated in the central stock status reports examined, the forecasted demand for the examined antibiotics remain relatively stable throughout the year (Medical Stores Limited, 2020a; (Medical Stores Limited, 2020b; (Medical Stores Limited, 2020c; (Medical Stores Limited, 2020d; (Medical Stores Limited, 2020e). However, it is important to note that the information acquired regarding average demand only ranges from March to August, implying a limited view on the effects of seasonality. For example, according to one of the ZAMMSA informants, diarrheal diseases are more commonly occurring during the rain season, resulting in seasonal surges in the use of specific antibiotic drugs.

Informants both at the ZAMMSA and the tertiary hospital pharmacies made it clear that the availability of medicines affected the prescription patterns of the bedside administration staff. An example brought up by the ZAMMSA's partner informant was the surprising number of patients at hospitals that are being prescribed a combination of Benzylpenicillin and Gentamicin in Zambia. This trend was attributed to bedside administration staff factoring in the historical availability of the drugs into the prescription decision, favouring medicines that previously had been available at the hospitals. Another ZAMMSA

informant argued that another possible reason behind the prescription pattern could be the unavailability of laboratory reagents, forcing physicians to administer empiric treatments in the form of broad-spectrum antibiotics to guard against the diagnostic uncertainty.

4.2 Healthcare Supply Chain Strategies

In this chapter, the strategic foundation, the strategies in the external healthcare supply chain, and in the tertiary hospitals' inventory management are investigated. Data presented allowed for an increased understanding regarding why stock outs of antibiotics occur at tertiary hospitals, furthermore suggesting how inventory management strategies employed at the tertiary hospitals could address antibiotic stock outs.

4.2.1 Strategic Foundation

The Zambian healthcare supply chain leading up to hospitals is a mixed pull- and push based system, with a decoupling point at the central warehouse run by ZAMMSA. National procurement is performed centrally based on forecasts, pushing stock into the system, while distribution downstream is incited by health facilities placing orders, pulling stock from the central warehouse. The informants interviewed did not provide any clear evidence toward the supply chain following a predominantly responsive or efficient strategy.

There appears to be some discrepancies between how the supply chain was designed to function and how it functions in practise. While secondary data sources suggest that the Zambian health care supply chain leading up to hospital is a pull-based system (Medical Stores Limited, 2013; Axios International, Inc., 2017), informants from ZAMMSA maintained that lacking availability at the central warehouse led to items being rationed to the facilities based on central planning, as they would in a push system.

4.2.2 External Healthcare Supply Chain Strategies

After having introduced the strategic foundation of the Zambian healthcare supply chain, this chapter presents the functions residing in the external healthcare supply chain, namely procurement and distribution.

4.2.2.1 Procurement

All public purchasing in Zambia must adhere with the Public Procurement Act No.12 (2008), defining the accepted methods and process of public procurement. The central procurement authority uses framework contracting to procure the essential medicines and medical equipment on two-to-three-year contracts that are selected through competitive bidding. Advance payment clauses are typically included in the contracts. During the contract period, the price of the products listed in the contracts are fixed, and cannot be changed by either party. As most healthcare commodities are procured from international actors, US dollars is the most commonly used transaction currency. Procurement orders are placed to the suppliers with whom a framework agreement has been signed when central replenishment is needed. For

purchasing orders placed within the framework contracts, an advance payment is included ranging up to 50%, with the remaining paid upon order fulfillment (MoH, 2017). GHIs perform their own procurement, delivering the items to the central warehouse where ZAMMSA assume responsibility for the distribution and downstream distribution. According to one ZAMMSA informant, the coordination of inbound supply from the GHIs was previously lacking, resulting in congestion at the central warehouse. However, one ZAMMSA informant maintained that this was resolved by improving the pipeline management, in which the increased inventory visibility and information sharing enabled by the installation of the eLMIS system played a key role.

In addition to the procurement performed by the central procurement authority and the GHIs, hospitals may also use 10 percent of their grant to procure healthcare items. This part of the hospitals' procurement grant is open, meaning that it is not earmarked for specific use and can be spent as the hospitals see fit. According to the hospital informants interviewed, there are two scenarios where the grant is typically used, namely: if a certain medicine is not included in the Zambian essential medicines list and hence not procured by the central procurement authority, or if ZAMMSA is stocked out of the requested medicine. In a report from 2019, the Center for Global Development claimed that drugs procured outside of the central procurement function typically incurred higher prices, and that this tendency is stronger when the HHI for suppliers of the drug in question is low (Center for Global Development, 2019).

As is the case in many LMICs, ineffective procurement practices and insufficient funding is a major issue in the Zambian healthcare supply chain according to ZAMMSA informants. These shortcomings lead to unavailability at the central warehouse, and informants from ZAMMSA and Zambian tertiary hospitals claim that the current situation is especially dire, with the central warehouse experiencing multiple and prolonged stock outs. Unable to attend the regular orders, this results in ZAMMSA being forced to operate on an emergency basis, diverging from the routine distribution schedule and rationing supplies to facilities.

One ZAMMSA informant argued that the main obstacle in the path toward securing effective procurement in Zambia is the lack of financial commitment and the untimely release of funds limiting the leeway of procurement operations:

> *"The commodities in [the essential medicines] category do not usually have funds committed to them throughout the fiscal period. So you usually find yourself in a situation where, if [essential medicines] are procured, they are procured under an emergency kind of an arrangement. So, a major bottleneck has been securing financial commitment for the essential medicines and antibiotics."*

Procurement is performed within framework contracts in which advance payments are stipulated. However, due to the shortage and inadequate disbursements of funds to the procurement function, payments to the suppliers are often delayed, leading to an accumulation of supplier debt. The MoH (2017) argues that the compounding of supplier debt risks pushing an already tight procurement budget to its limit through the accumulation of interest and penalty fees.

The situation of inadequate procurement funding is further exacerbated by the overall economic situation in Zambia. Between 2010 and 2020, Zambia's public debt surged from a debt-to-GDP ratio of 20 percent to 104 percent (IMF, 2019; African Development Bank Group, 2021), and depreciation of the local currency Zambian Kwacha (ZMW) have made the currency exchange rate between USD and ZMW increase with over 400 percent from 2013 to 2021 (Trading Economics, 2021).

In a report from 2019, the Center for Global Development claimed that the expenditures for procurement of antibiotics accounted for 6.9% of all drug procurement expenditures. This is illustrated in Table 4.3, where the procurement expenditures per therapeutic area is outlined for Zambia and compared to five other LMICs.

Table 4.3 - Procurement expenditure per therapeutic area in Zambia, compared with five other LMICs (including the state Kerala in India), reprinted from (Center for Global Development, 2021).

Area / Country	Kerala	Philippines	Serbia	SouthAfrica	Tunisia	Zambia
Anemia	2.51 %	3.93 %	1.70 %	1.25 %	1.61 %	.29 %
Antiulcerants	7.40 %	3.14 %	3.44 %	4.53 %	5.05 %	.13 %
Antihypertensives	7.78 %	14.94 %	18.41 %	8.87 %	12.94 %	.44 %
Antibiotics	17.30 %	18.14 %	7.97 %	12.64 %	20.27 %	6.11 %
Antiparasitics	.57 %	.20 %	.01 %	2.81 %	.39 %	5.83 %
Arthritis Immunosuppressants	5.16 %	5.32 %	8.48 %	5.93 %	8.34 %	.83 %
Asthma / COPD	8.89 %	4.90 %	6.73 %	4.23 %	3.79 %	.10 %
Cancer	.66 %	4.07 %	13.12 %	3.19 %	13.57 %	1.71 %
Contraceptives hormones	4.90 %	3.67 %	4.03 %	5.35 %	3.99 %	3.69 %
Diabetes	20.40 %	8.43 %	9.97 %	5.80 %	6.90 %	.22 %
HIV Antiretrovirals	.08 %	.01 %	2.03 %	9.14 %	.03 %	44.82 %
Lipid regulators	6.76 %	3.97 %	2.63 %	2.05 %	3.13 %	.05 %
Nervous system medications	6.11 %	3.17 %	11.09 %	7.68 %	6.81 %	.12 %
Pain Analgesics	2.51 %	6.04 %	4.31 %	8.86 %	6.74 %	1.21 %
Tuberculosis	.41 %	1.72 %	.01 %	2.81 %	.46 %	.54 %
Vitamins and Minerals	7.57 %	13.92 %	1.36 %	5.61 %	3.29 %	.21 %
Other	.92 %	4.36 %	4.62 %	9.17 %	2.60 %	33.62 %

4.2.2.2 Distribution

The backbone of the material flow in the Zambian healthcare system is the distribution schedule, dictating when each facility in the system receives their routine replenishment orders. Created once every half year and disseminated to the health facilities and other stakeholders, the distribution schedule is broken down into 73 routes and has a resupply interval of two months. Following the distribution schedule, orders are fine-picked for each facility at the central warehouse, and consolidated shipments are delivered to the regional hubs at where cross-docking operations are performed and the deliveries are made to the health facility in their catchment area. While ZAMMSA handles all routine last-mile distribution, they have also negotiated tripartite deals with the USAID (GHSC-PSM) project and private third-party logistics providers to assist in managing the distribution between the ZAMMSA central warehouse and the regional hubs.

To complement the routine replenishments, emergency orders are placed by hospital pharmacists whenever critically low stock levels at the health facilities are detected. This results in additional deliveries outside of the distribution schedule. Emergency orders are prescribed to be delivered to the facility in question within three days after the order has been processed. The delivery of emergency orders are managed by ZAMMSA, and transportation is performed either by ZAMMSA's fleet of vehicles at the central warehouse or by contracted third party logistic providers. According to one of the ZAMMSA informants, extending the mandate of third party logistics to respond to emergency orders was intended to collapse the lead times of emergency orders. However, the hospital informants claimed that they had not noticed any improvements. Although data is scarce, a study performed in 2017 pointed towards emergency orders being more common at secondary and tertiary hospitals (Axios International, Inc., 2017). In the study it was found that 37% of orders placed at secondary and tertiary hospitals were emergency orders, as compared to 10% at level 1 hospitals and 1% at health centres (Ibid).

One ZAMMSA informant argued that nation-wide distribution in Zambia is an inherently difficult and expensive task, with some health facilities located as far as 1200 kilometers away from the central warehouse in Lusaka. The situation is further complicated by the inadequate fleet of vehicles managed by ZAMMSA and the sometimes limited rural infrastructure necessitating last-mile deliveries to be performed by land cruisers, boats or even oxcart (MoH, 2019). At the time of the study, the distribution was experiencing an increased strain due to the erratic influx of Covid-19 supplies in the country. The same tendency was described in the case of erratic supply of other health commodities due to ineffective and untimely procurement. The ZAMMSA informants explained that these erratic deliveries competed with the routine distribution activities for financing and distribution capacity, further complicating the distribution.

According to the ZAMMSA informants, the lack of capacity resulting from the high influx of orders handled at the central warehouse necessitated increasing the resupply interval from one to two months. The newly adopted resupply interval of two months was deemed too infrequent to meet demand by the hospital informants, especially as they experienced that orders were not delivered within promised time nor in full quantity. In fact the USAID supply chain assessment (Axios International, Inc., 2017) suggested that only 50 percent of all routine orders to hospitals were delivered on time. This, according to the hospital informants, prompted an increased use of emergency orders.

The hospital informants also expressed concerns that emergency orders were not being delivered in time, and one of the informants explained that they sometimes were forced to use their own vehicles and personnel to collect the emergency orders from the central warehouse as a means to collapse the distribution lead time. These claims were strengthened by the USAID supply chain assessment (Axios International, Inc., 2017), in which none of the traced emergency orders were delivered on or before the promised delivery date, although it should be noted that all emergency orders to secondary and tertiary hospitals in the study were delivered no later than two days after the scheduled date.

4.2.2.3 Demand Forecasting

The demand forecasting is not uniform for all commodities in the Zambian healthcare supply chain. Forecasting for commodities managed by the disease specific programmes is handled by the GHIs

autonomously following their own procedures, while the forecasting of essential medicines, including most antibiotics, is performed by ZAMMSA and the MoH. The GHIs use hospital level consumption data as a proxy for demand as opposed to the issue data, i.e. shipment data from the central warehouse, used for the forecasting of essential medicines. The reason why issue data is used for essential medicines was, according to one of the ZAMMSA informants, that inconsistencies in the reporting by facilities made it difficult to capture accurate consumption data. GHIs have a more reliable and robust reporting system which allows them to capture consumption data directly. For essential medicines, the demand forecasting is performed centrally every three months by commodity area management teams under the MoH based on previous issue data to the hospitals (MoH, 2019).

Since the rollout and implementation of the eLMIS system, data can be captured and reported directly at the central level. To complement and cross-reference the central forecasting, an annual focusing and quantification meeting is held at which representatives from the hospitals partake. The forecasts are also validated by the use of a triangulation method, comparing the facility logistic data with stock issue and morbidity data (MoH, 2019).

Inaccurate forecasting was brought up as a concern by both the hospital and ZAMMSA informants. The root cause of these inaccuracies was believed to be the poor data quality of the data serving as a basis for the forecasting rather than the quantification methods used to analyse it.

There are two main reasons found to compromise the quality of the data used for forecasting. First, the order quantity calculated by using historic consumption or issue data, meaning that stock outs and erratic supply risks distorting the forecasting data. This issue was brought up both by the informants from ZAMMSA and the hospitals, confirming that in a situation where there has been a national stock out of an antibiotic for a prolonged period, the suggested order quantity by the eLMIS is zero. The erratic supply of essential medicines also made one of the hospital informants question the aptness of using issue data as a proxy for demand when replenishment orders from the central warehouse were delivered so seldom. Second, as previously mentioned, ZAMMSA informants argued that a lack of adherence to monitoring procedures such as continuously updating the eLMIS or replacing physical stock counts with estimates contributed to poor quality of forecasting data.

Adding to these issues, the Zambian health sector supply chain strategy and implementation plan (MoH, 2019) proclaim that the lack of coordination between the forecasting performed by the GHIs and the central forecasting performed for the remaining essential medicines led to a duplication of work.

4.2.3. Hospital Inventory Management Strategies

After introducing the strategic foundation of the Zambian healthcare supply chain and the strategies in the external supply chain, this section zooms in on the inventory management strategies employed at tertiary hospitals in Zambia.

4.2.3.1 Product Portfolio Management and Classification

The SKUs in the Zambian healthcare supply chain are not classified by using a conventional inventory management method such as an ABC-classification. Instead, all items are handled more or less uniformly once they have entered the healthcare supply chain. However, this could change in the near future according to an informant from ZAMMSA. A stock keeping strategy is being developed for the regional hubs in which the inventory is classified using a pareto analysis based on their order velocity, i.e. how often they are being ordered. If the strategy is implemented, strategic stock comprising high velocity SKUs will be stored at the regional hubs in addition to the central warehouse. This would, according to the ZAMMSA informant, allow the regional hubs to respond directly to emergency orders of strategic stock without involving the central warehouse. This proposed change was also reiterated in the MoHs Health Sector Supply Chain Strategy and Implementation Plan, where it was stated that cross-docking hubs were planned to be converted to stock-holding facilities (MoH, 2019).

All medicines available for use in the Zambian healthcare system are listed on the national essential medicines list. One hospital informant interviewed voiced concerns about the essential medicines list not encompassing all the medicines required by the hospitals. As a consequence, these medicines have to be procured using the hospital's open procurement grant, outside the normal procurement processes. This was found leading to increased procurement costs. According to the hospital informant, these increased costs occasionally led to the hospital failing to buy the drug, subsequently leaving the patient without adequate treatment.

4.2.3.2 Ordering

As is typical for actors in healthcare systems, tertiary hospitals in Zambia follow a mix of periodic and continuous review policies using a min-max control system. When a scheduled replenishment delivery is imminent, orders are placed on items for which the inventory level in the electronic logistic management system (eLMIS) has fallen below the reorder point (min-level), with the order quantity set to reach the maximum threshold (max-level). If the inventory level for an item falls below the emergency order point, an additional emergency order is placed. The inventory policy states the minimum and maximum thresholds of how many months of stock (MOS) that are to be held at the central warehouse, the regional hubs and the health facilities. The MOS for antibiotics is calculated based on historic issue data. When the system is down, a paper based system is temporarily used to register the inventory level and issue data, which is then retrospectively entered into the logistic system. The order-system logic is illustrated in Figure 4.6. The figure illustrates the different inventory levels at which orders are incited. Order sizes are based on the inventory level, which is tracked in the eLMIS system and cross-referenced with physical-inventory counts. The other data points illustrated in the figure include issue data, and consumption data. These are monitored and used in forecasting and as well as a basis for ordering.

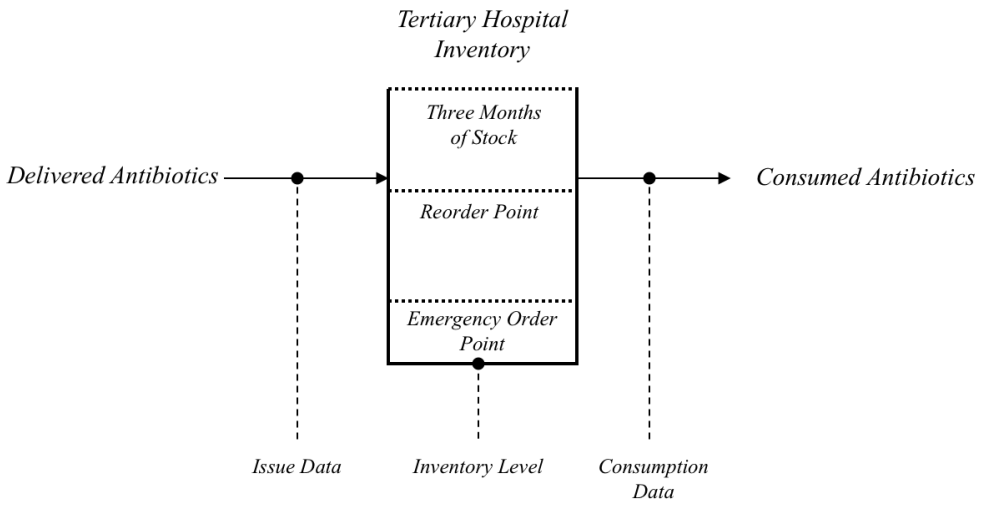

Figure 4.6 - A visual representation of the order-system logic.

The thresholds of stock keeping at each node in the public health system's supply chain are illustrated in Table 4.4 below:

Table 4.4 - Recommended stock levels (measured in MOS) in the Zambian health system supply chain

Supply chain node	Maximum stock level (MOS)	Minimum stock level (MOS)	Emergency order point (MOS)
Central Warehouse	9	6	-
Regional hub	Purely cross-docking, i.e. no planned stock kept[3]		
Hospitals	3	2	0.5

As the actual demand of healthcare items is difficult to track, the MOS is calculated using historical issue data as a proxy for demand. If the pharmacists find that the quantity suggested by the system does not mirror the facility's actual demand, they have it within their mandate to adjust the order quantity. According to a hospital informant, overriding suggested order quantities is a common procedure in the hospitals' pharmacies.

The minimum and maximum thresholds in the inventory policies at Zambian hospitals are configured to guard for the demand uncertainties when resupply orders are delivered in time and in full quantity. One of the hospital informants argued that the reorder points would be adequate if orders were delivered in full, but maintained that they proved insufficient due to the failure of ZAMMSA to deliver the requested order quantities. Both hospital informants underlined that the irregular supply was the single most important factor as to why hospitals experienced stock outs of antibiotics. Informants from ZAMMSA approved of this description and attributed the failure to deliver the ordered quantity in full to shortages of stock at the

[3] A stock keeping plan for the hubs is currently being developed by ZAMMSA.

central level. These claims were strengthened by a previous study conducted in Zambia (Axios International, Inc., 2017), in which order fulfillment was argued to constitute the biggest bottleneck in the ordering process. In the study, only 50% of all routine orders to secondary and tertiary public hospitals were found to be delivered on time. The study also showed that close to half (49%) of all routine orders placed by the health facilities had their order quantity adjusted. All of these adjustments were attributed to a lack of availability at the central warehouse: two-thirds (67%) to stock outs and one third (33%) to insufficient stock levels. One of the ZAMMSA informants argued that the failure to deliver the requested order quantity created a negative feedback loop, compounding emergency orders and putting additional pressure on the distribution capacity. As one of the ZAMMSA informants explained:

> *"When we have inadequate stock coming in, we are inadequately fulfilling orders. This means that facilities will also trigger more emergency orders, causing a vicious circle."*

However, one of the hospital informants indicated that there is no easy solution to the problem, as the hospital pharmacies are struggling with inadequate storage capacity despite inventory levels being depleted as a result of insufficient supply. If the pharmacy would be stored according to plan, the informant argued that the situation would become unsustainable:

> *"If you had to come into the [hospital pharmacy's] storage facility, you would probably think that storage space is sufficient, but that's only because we currently don't have enough drugs. Still, we sometimes have to look for space outside of the actual pharmacy to store all our drugs."*

However, while the hospital informants maintained that the shortcomings of the order processed stemmed almost exclusively from the upstream operations in the supply chain, this picture was not shared by the ZAMMSA informants. The informants gave examples of both under- and over ordering. One of the ZAMMSA informants argued that inflated orders were the major cause of concern, resulting in bullwhip effects and superfluous stock being ordered at the central level. Another ZAMMSA informant instead maintained that underreporting was a bigger issue, and claimed that some facilities systematically only reported on a selection of items deemed most important for the management of the health facility. Moreover, one the informants raised concerns about orders from hospitals not being placed in time to be processed before the scheduled delivery, resulting in routine orders being converted into emergency orders. One of the hospital informants agreed with SOPs not always being followed, but instead attributed this to a failure from ZAMMSA fulfill orders:

> *"If you put in your order today, and it hasn't been delivered a month later or if it hasn't been delivered at the scheduled date, then you would have to put in an emergency order. And sometimes emergency orders are not honored either, and you would definitely have to put in another order. So of course, yes, some standard operating procedures are not followed."*

4.2.3.3 Monitoring and Counting

The inventory levels and the consumption at Zambian hospitals are continuously tracked in the eLMIS system. The eLMIS data govern the ordering process, deciding when an order should be placed and in what quantities. The reason why issue- instead of consumption data was used for essential medicines was,

according to one of the ZAMMSA informants, that inconsistencies in the reporting by facilities made it difficult to capture accurate consumption data. GHIs have a more reliable and robust reporting system which allows them to capture consumption data directly.

To ensure that the orders placed are correct, orders are checked for irregularities by ZAMMSA personnel to identify irrational ordering patterns and pack size misinterpretations. The inventory levels in the eLMIS are also cross-referenced through an exhaustive physical count of all stock performed once every month by the hospital pharmacists, following a periodic-count method.

Informants from ZAMMSA maintained that a lack of monitoring capacity distorted forecasts and led to incorrect ordering. Capacity and time restraints paired with a large product portfolio managed at the hospital level was thought to lead to pharmacists estimating the stock levels rather than performing a physical count. In turn, suspended cross-referencing was believed by the ZAMMSA informants to be the cause of discrepancies between the actual and the digital inventory levels not being detected. These discrepancies were also attributed by the ZAMMSA informants to movements of stock occurring during periods of system malfunction not being entered retrospectively into the eLMIS.

4.3 Summary of Key Findings

The key empirical findings for the case are outlined in figure 4.7. The findings are categorised based on the conceptual framework.

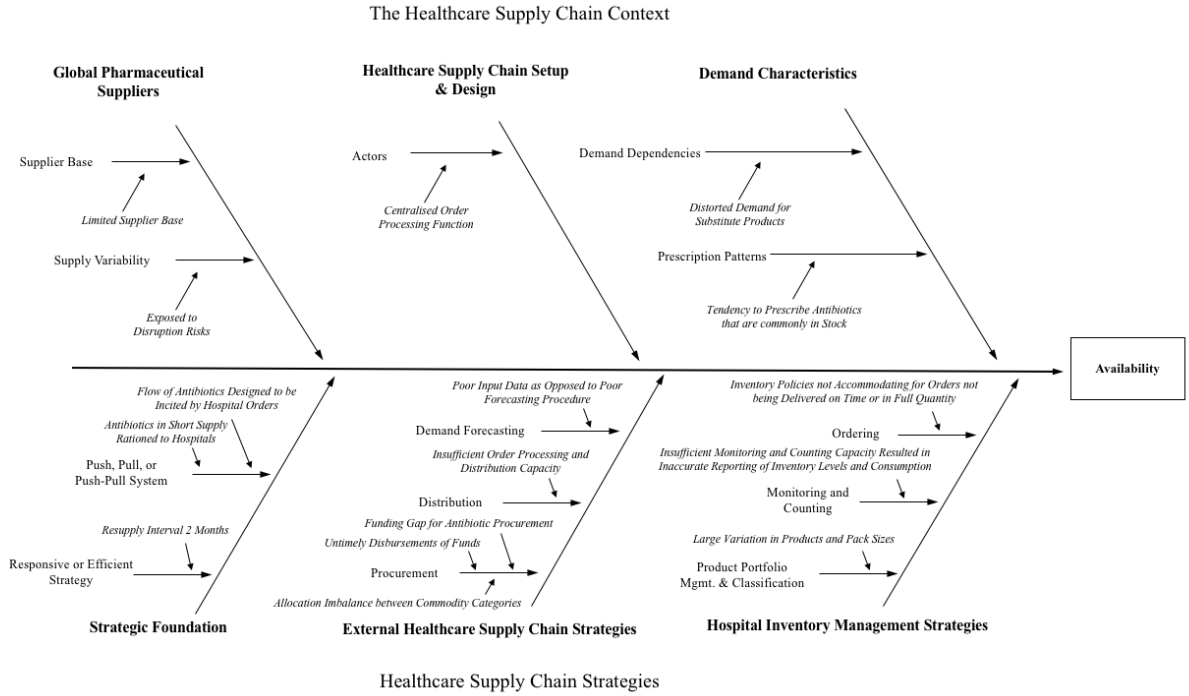

Figure 4.7: Case aspects that contribute to antibiotic stock outs.

5. Analysis and Discussion

Based on the theoretical foundation established in the frame of reference, and building on the empirical data collected through interviews and the secondary data study, we have identified some main themes for analysis and discussion. The purpose of the section is ultimately to answer the research questions. The first part of the analysis will focus on establishing the causes of antibiotic stock outs at tertiary hospitals, and discuss how literature supports an explanation of why these stock outs occur and how they can be connected with inventory management processes and functions. In the second section, we analyse and discuss how inventory management strategies investigated in the frame of reference can address stock outs, given the Zambian healthcare supply chain context and strategies as determined in the empirical data collection.

5.1 Causes of Stock Outs

While the empirical evidence gave conflicting accounts for some of the identified reasons behind stock outs, all of the evidence collected pointed at budget constraints or insufficient funds being a chief cause of stock outs. The lack of funds was found to be both a direct and indirect cause of stock outs. The direct cause is straightforward to identify: there were insufficient funds to procure the amount of antibiotics that were in demand. The indirect consequence is more difficult to pinpoint, but can be summarised as the lack of funds available to finance and effectivize supply chain processes. Similarly, while many inefficiencies in the supply chain do not comprise direct causes of stock outs, they can be considered to indirectly cause stock outs due to ineffective use of funds. This stands to show that the opportunity costs for many identified supply chain inefficiencies are great. In other words, by identifying any utility that could have been appreciated through a different design configuration, strategic foundation, inventory policy, et caetera, we identified indirect causes of stock outs.

In this section, we discuss the causes of antibiotic stock outs at tertiary hospitals by integrating the empirical data with supply chain theory presented in the frame of reference. The supply chain shortcomings that contribute to stock outs have been analysed using the conceptual framework. The analysis presented in this section will build knowledge necessary to answer research question one.

5.1.1 The Healthcare Supply Chain Context

In this section, the findings relating to the healthcare supply chain context in Zambia are analysed and discussed, on the basis of the theoretical foundation established in the frame of reference.

5.1.1.2 Global Pharmaceutical Suppliers

In the frame of reference it was made clear that the global pharmaceutical suppliers have a profound impact on the availability of antibiotics on a national level, and in extension, on the occurrences of stock outs of antibiotics at tertiary hospitals. Since Zambia has an insignificant domestic production of medicines, it is highly dependent on the global pharmaceutical companies to supply the healthcare system with medicines. The high HHI for antibiotics indicate that Zambia to a great extent is reliant on a few

number of suppliers, exposing the Zambian antibiotic supply chain to global disruptions and rendering their purchasing power weak. Huff-Rousselle (2012) claims that pharmaceutical suppliers often use their market control as leverage against the purchasing part, and we argue that this likely increases the prices of procured antibiotics in Zambia.

Secondary data sources pointed to what was referred to as a market failure of antibiotics. This was compounded partly by the low profit margins for antibiotic drugs. Moreover, we found that there was a lack of an institutional procurer acting as a guarantor for timely payments, ensuring long-term financial commitment and consolidating demand forecasts to the global pharmaceutical suppliers. In this failed market, pursuing short-term profitability by way of cutting costs is promoted at the expense of ensuring a steady supply of antibiotics and hedging for disruptions. While the volatile antibiotic market might not affect day-to-day operations, the Zambian healthcare supply chain is left vulnerable to global disruptions and shortages due to the lack of domestic medicine production. Furthermore, the demand dependencies between many different antibiotic drugs render ripple effects a likely effect of global shortages, as demand for substitute drugs is likely to surge. It is reasonable to assume that a global shortage would give rise to an increased competition between nations and procuring entities, leaving actors with weaker purchasing power behind. We found that similarities could be drawn with the currently overheated market for covid vaccines, where high-income countries have secured the majority of the global supply despite calls for global solidarity.

5.1.1.2 The Healthcare Supply Chain Setup and Design

In the empirical data collection, we found that the healthcare supply chain has undergone several disruptive changes over the last years, one of the most noteworthy being the change of the supply chain design and allocation of responsibilities. This entailed a centralisation of warehousing operations, the implementation of cross-docking hubs, and a dramatic increase in the number of incoming orders to the central warehouse. With regard to possible shortcomings in the Zambian healthcare supply chain design, we found that the issue had to be approached by considering the limitations under which the supply chain labours. In terms of limitations, the empirical evidence suggested that inter alia budget constraints, reliance on few suppliers, and limited capacity for supply chain operations in general, limited the possibility of resolving stock outs solely by way of design measures. We furthermore found that the empirical data on design and setup aspects did not provide enough evidence to directly attribute stock outs to shortcomings in the healthcare supply chain setup and design. In fact, the change of supply chain design was implemented following the completion of a randomised trial in which the cross-docking model was found to have the greatest impact on mitigating stock outs. However, in this trial, distribution was performed monthly, instead of bimonthly as it is today.

In spite of the fact that some of the evidence suggests that the design and setup accommodates for many of the limitations imposed on the healthcare supply chain in Zambia, we speculated that some shortcomings in the newly reformed design could still explain the occurence stock outs, albeit indirectly. For example, we found that the centralisation of order processing functions implied an elevated capacity strain on the central level, in turn leading to longer resupply intervals and a greater exposure to stock outs as a consequence of supply chain uncertainties. This increase in order batching augments possible bullwhip effects, through what is referred to as the Burbidge effect.

With longer resupply intervals, there was a greater need to hedge for demand variability and supply erraticity, calling for heightened inventory levels and reorder points at the hospitals. At the same time, research suggests that a cross-docking system can imply an even greater need for storage capacity at point of service, than in a corresponding system with inventory at an intermediary supply-chain node. We argue that the design changes influenced the appropriate inventory settings at the hospitals, as the hospital pharmacies after the change needed to accommodate for demand, and hedge for supply chain uncertainties for a time period twice as long as before the design change.

While both the increase in resupply intervals and the implementation of cross-docking necessitated higher inventory levels at the hospitals, empirical evidence suggested that inventory levels were almost systematically too low in light of the recurring supply disruptions. Also, we found that the storage space at the hospitals would prove inadequate for accommodating for 100 percent order fulfillment. This suggested that neither the external healthcare supply chain functions nor the hospital pharmacies' storage space were aligned with the design of the overall supply chain. In fact, the hospital pharmacy informants described a rather peculiar situation, where the high incidence of stock outs made a general lack of storage space manageable. This underlines the importance of including the storage capacity at hospitals as a modeling constraint when addressing stock outs, implying that the storage capacity at tertiary hospital pharmacies must be increased in parallel with other configuratory or operational changes aimed at mitigating stock outs.

In light of the recent changes made to the healthcare supply chain, we considered whether any shortcomings in the configuration of the system could be attributed to a flawed supply chain design or a lack of funding to uphold the operations in the system, or if it rather could be attributed to an incomplete transformation process. The fact that the role of cross-docking hubs were being reconsidered, with the intent on converting them to stock-holding facilities, gave credence to the hypothesis that there were some shortcomings in the initial design. Due to the lack of consensus with regard to the relationship between stock outs and supply chain setup and design aspects, we propose that the identified shortcomings in the supply chain design is a subject for future research. A future replication of our study or future research on Zambia's healthcare supply chain design could potentially validate or reject the competing hypothesis that stock outs can be attributed to an incomplete transformation process or possible extraneous variable effects, as opposed to shortcomings in the supply chain design.

5.1.1.2.1 Healthcare Supply Chain Actors

Much like its counterparts in other LMICs, we found that the healthcare supply chain in Zambia had a complex administrative structure that was fragmented between separate supply chain actors; regulatory authorities, government ministries, ZAMMSA and GHIs all hold mandates that encompass different components of the same operations. A propos the overlapping mandates, Yadav (2015) suggested that healthcare supply chains in LMICs frequently suffered from a fragmented accountability structure, and that this was also considered to be a common cause of antibiotic stock outs. In effect, we had expected that stock outs in Zambia could be attributed to a failure to hold responsible supply chain actors accountable for shortcomings. However, we did not find any evidence that validated this hypothesis.

While a fragmented accountability structure did not seem to be a major issue in the Zambian healthcare supply chain, a lack of harmonised objectives between the actors in the supply chain was hypothesised to lead to silo thinking. This is symptomatic for healthcare supply chains in LMICs, and we have found that earmarked funding and a duplication of work in Zambia has led to a suboptimal allocation of resources. While a SWAp was implemented in the Zambian healthcare sector as early as 1993, research suggests that GHIs active in the country operate predominantly following their internal committees and structures, indicating that a single-sector program is not de facto followed. We found that the failure to completely follow a single-sector approach, in addition to the heavy involvement of international donors and disease-specific programs, perpetuated the finance-allocation imbalance in favour of disease-specific initiatives with strong agendas. This trend is especially worrying considering that increased resilience is dearly needed to increase the resilience of the supply chain and allow for an increased flexibility to fill the gaps of underfunded areas. By stripping the MoH of some of its autonomy in strategic areas such as procurement and forecasting, we argue that the process toward building national capability is hindered, further increasing the reliance on external actors. The empirical data collection furthermore indicated that antibiotics specifically were considered to be a financially neglected therapeutic area as compared to for example HIV-AIDS. Since we have not found any evidence that indicated whether or not the allocation of funds to HIV-AIDS was unproportionally large, we do not want to suggest that antibiotics should be procured at the expense of HIV-AIDS treatments. We do, however, encourage that more research is conducted to explore how the tug of war for funds between health initiatives and supply chain actors can be resolved, and how the allocation of funds to the procurement of antibiotics could be increased.

A propos unproportionate allocation of funds, empirical evidence also indicated that there was a tendency to down-prioritise the allocation of capacity and resources to routine operations as opposed to capital projects and emergency responses. This is typical for healthcare supply chains in LMICs. ZAMMSA informants, in addition to both the hospital informants interviewed, indicated that the operational focus on procurement is unproportional as compared to the focus on covering other operating expenses in the external healthcare supply chain and hospital. Yadav (2015) suggested that one of the reasons behind this tendency could be that the funding of supply chain operations comprised a politically unattractive alternative to capital projects and emergency responses.

The empirical evidence suggested over-ordering and insufficient information sharing resulted in bullwhip effects. Both insufficient information-sharing and the tendency of over-ordering is typical for healthcare supply chains. Research partly attributes this to contractual agreements and the pressure for each actor to pursue efficiency. We found that healthcare supply chain actors in Zambia laboured under resource scarcity and a high level of scrutiny as to how public funds were being used, giving us reason to believe that each actor was in constant pursuit of efficiency. If the relationships between actors are not managed holistically, but on a contractual basis, we speculate that the efficiency objectives can lead to silo-thinking. However, we have found no evidence that would suggest that contractual agreements between stock-keeping actors in the Zambian healthcare supply chain is a cause of concern. We assessed this to be reasonable, since ZAMMSA has oversight of the supply chain operations from procurement to last-mile delivery. We found that ZAMMSA and their cooperating partners influenced inventory management strategies employed at hospitals by setting national standards of operation. Moreover, we assessed that the very limited autonomy of individual actors in the supply chain reduced the risk of actors pursuing internal efficiency at the expense of other actors.

With regard to actors, more specifically different hospitals, we found that there were discrepancies in terms of how well the healthcare supply chain accommodated the needs of the different levels of healthcare. Previous studies have shown that secondary and tertiary hospitals in Zambia utilised emergency orders more regularly than smaller health facilities. We speculated that this could be attributed to the fact that it was considered more urgent to attend to tertiary hospitals as compared to smaller facilities. It is reasonable to assume that emergency orders to facilities providing more critical care are prioritised, due to the importance of not compromising life-saving treatments at these facilities. We also speculated that the supply chain was unfit to respond to the greater demand uncertainty that providing a more specialised care entails, which would increase these facilities' reliance on emergency orders. Another possible explanation is that the ample product portfolio in use at tertiary and secondary hospitals was not efficiently managed, with discrepancies in for example demand forecasting. All of the aforementioned themes for discussion raise the question of whether it could be beneficial to more carefully tailor the distribution schedule and inventory policies to tertiary and secondary hospitals. We therefore encourage that future research is conducted on the potential trade-off between tailored settings and collapsed supply chain standardisation.

5.1.1.3. Demand Characteristics

Previous research suggested that the demand for antibiotics is affected by a wide variety of factors such as the disease panoramas of the hospitals' catchment population, demand dependencies between healthcare commodities, and the physicians' personal preferences. The empirical data provided evidence that this was true for Zambia as well. Interestingly, we also found evidence that the lack of availability influenced the prescription patterns of bedside administration staff. This in turn was found to affect the demand of antibiotics, both in a direct and an indirect manner.

We noticed a tendency towards prescribing medicines that were commonly available at the hospital rather than those suggested by the treatment guidelines. We argue that recurrent stock outs of specific antibiotics could risk cementing suboptimal treatment patterns, where regularly available substitute drugs are prescribed instead of first-line treatments. Similar to what previous research suggested, diagnostic uncertainty caused by a lack of laboratory reagents compelled clinicians to prescribe antibiotic treatment empirically. The informants argued that this led to an increased use of broad-spectrum antibiotics, as a means to ensure effectiveness against a wide array of possible bacterial strains. We argue that the increased use of broad-spectrum antibiotics risked leading to an increased risk of AMR and we therefore suggest that it could form an interesting topic for future research in the Zambian healthcare context.

Furthermore, the empirical data showed that stock outs could indirectly influence demand by distorting the issue data used as a basis for forecasting. In the case of a shortage at the central level, no replenishment deliveries of the stocked-out drug will be issued while the actual demand for the medicine remains the same. As a consequence, the discrepancies between actual demand and issued quantities may lead to the demand for the drug being underestimated. We argue that this could result in lower quantities of the medicine being delivered to the hospital and less funding being allocated to the drug in the procurement planning, further increasing the risk of stock outs. Antibiotic stock outs therefore risk

creating a negative feedback loop, where the unavailability of a specific antibiotic drug increases the risk of future stock outs of the same drug.

5.1.2 Healthcare Supply Chain Strategies

In this section, the findings relating to Zambia's healthcare supply chain strategy are analysed and discussed, on the basis of the theoretical foundation established in the frame of reference.

5.1.2.1 Strategic Foundation

The study has found that there was a lack of strategic alignment between the strategic foundation and the reality the supply chain was faced with.

Between ZAMMSA and the tertiary hospitals, evidence suggested that the supply chain was foremostly modelled to function as a push-pull system, with antibiotics being pushed to a decoupling point at the central warehouse, from where stock would be pulled by health facilities. As such, operations upstream of the hospitals were designed to be responsive to demand signals conveyed from the hospitals. When the supply chain became subject to antibiotic stock outs, antibiotics were rationed to facilities based on forecasts as opposed to being incited by demand signals. We argue that this is synonymous with moving the decoupling point downstream for these particular products, in these particular instances. As a theme for discussion, we analysed the possible implications of shortages at the central warehouse resulting in the decoupling point de facto being located further downstream than it was designed to. In order to assess how operational inefficiencies caused by a lack of strategic alignment related to stock outs, we considered the opportunity costs of this strategic misalignment.

Table 2.3 in the frame of reference indicates that a decoupling point located at the central warehouse (as compared to the hospital) necessitates greater responsiveness in the supply chain, robust order handling capabilities at the hospitals, and shared incentives. Furthermore, it indicates that if orders can be expedited responsively, a supply chain with a decoupling point at the central warehouse (as opposed to the hospital) is less sensitive to forecast errors. On the other hand, it would also likely entail that capacity utilisation on a central level becomes more strained and variable, suggesting that opportunities to utilise economies of scale are slimmer.

We argue that the empirical data pointed towards a lack of alignment between the strategic foundation and the reality the supply chain was faced with. We hypothesise that this can be explained by a lack of financial or operational capacity to coherently fulfill prerequisites for maintaining a responsive strategy and continuously pulling stock from the central warehouse. In opposition to the intended strategy, we found that orders of antibiotics that were in short supply were incited by way of rationing as opposed to being incited by demand signals. We assessed this to be a relevant concern for this study, considering that central stock outs of many key antibiotic drugs was described to be a major issue. Furthermore, the lack of central capacity stipulated that the distribution system had to be configured with long resupply intervals, rendering the system's response to demand signals from hospitals slow and unsynchronised. While systems in which the decoupling point is located further up the supply chain generally do not require the same level of forecasting, this is only true if the system can maintain a certain degree of

responsiveness to demand signals. Therefore, we argue that this is not necessarily true for the Zambian healthcare supply chain, where routine deliveries were scheduled and infrequent. While we found that the pull mechanism in the Zambian healthcare supply chain took the order quantity into account, orders placed by hospitals did not incite distribution *on demand*, since this was prescheduled. Therefore, we argue that the responsiveness to demand signals was somewhat limited. While the complementary emergency order system allowed orders to trigger additional deliveries on demand, we argue that the responsiveness provided by the emergency order function often did not suffice, since emergency orders sometimes failed to be delivered due to a lack of distribution capacity or, in some cases, as a consequence of central level shortages.

With regard to the possible opportunity costs discussed above, we also considered alternatives to the system in place. An important theme for discussion was therefore whether a more incremental approach could have been adopted as a remedy to supply chain shortcomings, or if a more pivotal approach should have been opted for instead. We considered that an incremental approach would entail directing efforts towards adapting current inventory management functions to cope with the shortcomings of the current strategic foundation. A pivotal approach, on the other hand, would imply more pivotal changes made to the strategic foundation. This could for example entail reconfiguring the supply chain as a push system, or transitioning to a more resource-efficient strategy, in light of the financial and operational capacity limitations imposed on the healthcare system. We considered this to lie outside of the scope of this paper, but nonetheless, we stress that readers should keep in mind that the paper has identified this crossroads.

5.1.2.2 External Healthcare Supply Chain Strategies

In this section, shortcomings in the external healthcare supply chain strategies that were thought to cause stock outs are discussed, combining findings from the empirical data and the literature reviewed in the frame of reference.

5.1.2.2.1 Procurement

We found that ineffective procurement was a strongly contributing factor leading to stock outs in the Zambian healthcare supply chain. The empirical evidence suggested that there were mainly two issues that rendered procurement ineffective. First of all, we found that a chief issue was that medicines were not being procured in sufficient quantities to meet the demand at tertiary hospitals. We also found that this issue could be further dissected by considering both the available funding for procurement, and the affordability of procured antibiotics. Funding constituted an issue not only with respect to the accumulated quantities of healthcare commodities that could be procured, but also with respect to the imbalanced allocation of funds between commodity categories. The empirical data provided clear evidence that donors in general and GHIs in particular had a strong influence on the healthcare system's procurement budget. This was found to result in disproportionate shares of funds being allocated to the procurement of commodities managed by the GHIs. We argue that this reduces the flexibility to fill the funding gap for other therapeutic areas, such as antibiotics. We found this to be a cause of concern that was furthermore aggravated by the trend that an increasing share of the donor funding was being earmarked, targeted for use in specific regions or programs. In this regard, we found that stock outs could

be attributed to insufficient funds for antibiotic procurement, as well as the relative negligence of antibiotics by GHIs.

We hypothesise that the fact that antibiotics were not procured in sufficient quantities also could be attributed to elevated procurement prices. In the secondary data study, we found that the HHI for antibiotic suppliers in Zambia amounted to 61.9%. While this performance was found to be somewhat superior to other therapeutic areas in Zambia, it still implied that there was little supplier competition between antibiotic suppliers. Center for Global Development (2021) suggested that reliance on few suppliers is likely to lead to elevated prices, and greater exposure to supply chain disruption.

The second issue that rendered procurement ineffective, was that drugs were not procured in due time. ZAMMSA informants claimed that erratic procurement resulted in spikes in the country's inbound supply of antibiotics. This phenomenon added strain to the already exhausted distribution capacity, but also had the unwanted effect that antibiotic orders from hospitals were delivered on a when-and-if-available basis rather than on demand. We found that untimely procurement could be explained to be the consequence of several factors, the most prominent being the untimely disbursement of funds for procurement. Similar to its counterparts in other LMICs, the healthcare supply chain in Zambia laboured under circumstances characterised by limited funds in general, and a lack of long-term financial commitment in particular. We found that the lack of long-term financial commitment led to antibiotics being foremostly procured and pushed to the decoupling point based on a 'sense of urgency' rather than as a proactive measure. At the same time, the potential success of the pull-system strategy downstream of the decoupling point was found to be conditional on the availability of stock at the decoupling point, making proactive procurement a prerequisite for a well functioning supply chain.

The insufficient and untimely disbursing of funds to procure healthcare commodities was also found to be affected by the Zambian debt burden. The secondary data study suggested that outstanding debts to pharmaceutical suppliers risked damaging the supplier-procurer relationship and trust. Furthermore, the failure to pay suppliers in due time pushed an already tight procurement budget to its limit through the accumulation of interest and penalty fees. This situation was further complicated by the continued depreciation of the local currency, Kwacha. This trend was found to affect the purchasing power vis-a-vis the global pharmaceutical suppliers, with whom contracts were signed in USD. Due to the contractual relationships characterising the health care system, there seemed to be an increased emphasis on the short-term fulfillment of contents specified in the contract, rather than a focus on creating long-term value through mutual development. This implies that the inability to meet the payment terms stated in the contract could prove detrimental to the Zambian healthcare system, and risks having immediate consequences.

In summary, we found that shortcomings in the procurement function had a direct impact on the availability of antibiotics at the central warehouse, and in extension, the availability of antibiotics at tertiary hospitals. In fact, all the informants interviewed assessed that a large share of stock outs at tertiary hospitals could be attributed to unavailability on a central level either directly or indirectly. The direct connection is obvious: as stock is in short supply on a central level, order fulfillment of downstream supply chain actors is naturally impeded. The indirect connection is somewhat more complex but

nonetheless influential: when the supply chain frequently becomes subject to nation-wide shortages, the actors of the supply chain will likely employ mitigation strategies to decrease the effects of stock outs.

5.1.2.2.2 Distribution

Zambia is a geographically dispersed country, and managing the distribution of healthcare commodities to the healthcare facilities in every province requires a well functioning distribution system and an adequate fleet of vehicles. We found that the private sector almost exclusively operated in densely populated urban areas. In effect, ZAMMSA, responsible for the distribution of healthcare commodities in the public healthcare system, carried the brunt of the distribution burden. The empirical data gave evidence to the distribution system in Zambia being underfunded, both in regards to the fleet of vehicles managed by ZAMMSA and the operational capacity to prepare outbound orders from the central warehouse. We hypothesize that this could be attributed to operating expenditures not being a politically appealing investment as opposed to capital projects, a notion that was echoed by one of the ZAMMSA informants claiming that the focus on procurement obscured potential areas of improvements in the downstream supply chain.

Despite the replenishment interval of the distribution schedule having been increased from one to two months, we noted that the capacity at the central warehouse was limited, both in regards to order preparation and distribution. This was illustrated by the fact that distributions of both routine and emergency nature often were delayed. We argue that delayed order constituted a chief cause of stock outs of antibiotics. Furthermore, we suggest that the lack of buffer capacity rendered the system vulnerable to disruptions and periods of increased workload. The empirical data supported this notion, and informants described a vicious cycle, where responsiveness to emergency orders was pursued at the expense of responsiveness for day-to-day routine operations.

Tertiary hospitals were found to place emergency orders to a larger extent than other service-providing health facilities. We argue that this points towards the routine distribution system being insufficiently robust to meet the needs of tertiary hospitals. While emergency orders played an important role in increasing the responsiveness of the distribution system, we argue that the opportunity cost and capacity strain exerted by the current use of emergency orders could outweigh the benefits. Deliveries to tertiary hospitals are delivered separately, that is, they are not consolidated with orders from other facilities nor cross-docked at the regional hubs. We argue that this could allow for altering the replenishment frequency to tertiary hospitals only, without necessarily altering the replenishment interval of the entire system.While suggesting changes to the distribution functions lie outside the scope of this study, we suggest that this could be an interesting topic for future research.

The strain that emergency responses put on routine distribution operations was found to be a yet more current issue in the age of Covid-19. In fact, ZAMMSA informants mentioned that a similar trend prevailed in the outbreak and wake of the pandemic. Due to the fact that logistic processes for Covid-19 supplies ran concurrently with routine operations, informants expressed concerns for how the pandemic had put strain on an already exhausted supply chain. The threat was compounded by the nature of supply that is typical for healthcare commodities, but somewhat extreme for Covid-19 supplies: as a result of the global scramble for supplies, the inbound supply of for example vaccines and PPEs on a central level was

erratic and difficult to predict. As a result, Covid-19 supplies had to be disseminated to hospitals whenever they trickled in, paralysing some of the other routine operations in the process. This trend seemed to be somewhat symptomatic for pandemic response actions in healthcare supply chains, and a similar trend could be observed with regard to capacity allocation of bedside personnel. According to Ma et al (2020), referring to Covid-19 responses at epicenters in LMICs, *"the explosive number of COVID-19 patients has pulled surgical staff out of operating rooms into the emergency department and intensive care units"*. We suggest that future research can be conducted to study how the consumption of antibiotics interplay with changes in allocation of service provision, and how the expected change in prescription patterns affect demand signals communicated upstream. This is not least relevant to provide insights as to how AMS programs can affect the upstream antibiotics supply chain and vice versa.

While not mentioned as an issue for the tertiary hospitals represented in the interviews, we argue that the opportunity costs for emergency orders were unnecessarily high for facilities located far away from the central warehouse. As no stock was kept at the provincial or district level, emergency-order response deliveries sometimes travelled vast distances to supply a single hospital. Informants from ZAMMSA indicated that they were currently looking into prepositioning stock for high-velocity items at the ZAMMSA hubs as a means to mitigate the risk for stock outs for these items, for the purpose of increasing the responsiveness in expediting emergency orders. This change implies pushing the decoupling point for these items and order type downstream in the supply chain. Table 2.3 in the frame of reference supports this notion to some extent, as moving the decoupling point downstream has the potential to reduce emergency order lead times for these items. Furthermore, Liu et al. (2020) suggest that moving the decoupling point downstream can increase capacity utilisation upstream. Even though the proposed change would only be implemented for a selection of products and for emergency orders only, it is reasonable to expect some capacity otherwise allocated to expediting emergency orders for high-velocity items will be alleviated. Informants from ZAMMSA underlined that capacity restraints upstream with regard to warehousing operations and distribution imposed a limit to how often distribution to hospitals could take place; the routine distribution schedule was set to bimonthly deliveries as this is the most frequent schedule that ZAMMSA could cope with. We believe that the opportunity costs and capacity strains of emergency orders and the ineffective capacity utilisation at the central warehouse constitute causes of stock outs and therefore believe that this would be an interesting area of research, albeit outside of the scope of this study.

5.1.2.2.3 Demand Forecasting

We did not find any empirical evidence pointing towards inadequate quantification methods being used. Rather, the empirical data collected indicated that the forecasting shortcomings could mainly be attributed to poor quality of the data used in the quantification process. The poor data quality was found to be the result of discrepancies between issue data and actual demand.

While the real demand for antibiotics is not affected by disruptions and stockouts, consumption and issue data used as proxies for demand are considerably affected. The large majority of antibiotics in the supply chain are not managed by GHIs, and consequently, their demand is calculated using issue data. We argue that the discrepancy between demanded antibiotics and issued antibiotics constitutes one of the chief difficulties in gauging the future demand for antibiotics at the hospital. While using issue data as a proxy

for actual demand is likely effective in contexts where drug supply is frequent and unimpeded, we argue that antibiotic stock outs at the central warehouse compromise the analogy between what is demanded and what is issued. For example, if amoxicillin is out of stock at the central warehouse for a prolonged period of time, no replenishments would be delivered to the hospital. This entails that the calculated demand would amount to zero, in spite of the fact that the actual demand for the drug would likely have been unfaltering. The empirical data supports this notion, and hospital informants were concerned about large discrepancies between actual and calculated demand due to replenishment orders being issued too infrequently. While we found that this was to some extent mitigated in the ordering function, where pharmacists could manually override suggested order quantities, we argue that the phenomenon is still a cause for concern. We argue that this could lead to non-standardised ordering, an increased workload for the hospital pharmacists and a risk of incorrect order quantities being entered.

The problem with treating issue data as an accurate reflection of demand is also compounded by changing prescription patterns and the switch to substitution treatments. It has not escaped our attention that a stock out of one antibiotic drug often inevitably leads to the subscription of an alternative substitute drug. In effect, not only demand for the antibiotic drug in short supply is inaccurately reflected by reported consumption, but also that of the substitute drug.

5.1.2.3 Hospital Inventory Management Strategies

In this section we will analyse and discuss the inventory management strategies employed at tertiary hospitals in Zambia, and how possible deficiencies were found to lead to stock outs of antibiotics at tertiary hospitals.

5.1.2.3.1 Product Portfolio Management and Classification

The empirical evidence suggested several shortcomings in the hospital pharmacies' product portfolio management. On one hand, the Zambian essential medicines list did not encompass all medicine needed for the functioning and service provision of tertiary hospitals. In some cases, this was found to render some critical treatments unattainable. In other instances, it led to hospitals procuring the medicines in question outside of the central procurement processes using their own procurement grant, likely leading to increased procurement costs. In the interview study, informants substantiated the issue by giving account of how the elevated costs of using the hospital grant to procure drugs overlooked by the essential medicine list left patients without adequate treatment.

In spite of the fact that some products were not procured or made available at hospitals, we found that the large variation in products and pack sizes still left hospitals struggling with managing their product portfolio and complying with their intended inventory policies. The empirical data provided us with evidence of how limited monitoring capacity and manpower at hospital pharmacies resulted in non-adherence with SOPs. Research suggests that limited capacity for product portfolio management to some extent could be remediated by strategically allocating capacity between the products in the portfolio. Interviewed informants gave accounts of this being done already, albeit in an unsystematic fashion. In these cases, we found that hospital pharmacists strategically allocated capacity based on their own judgement of criticality and urgency. However, these decisions essentially circumvented the SOPs for

monitoring. When unable to exhaustively count the inventory due to capacity restraints, it was reported that pharmacists sometimes skipped inventory counts of items they deemed less important for the hospitals' operations, making estimates instead.

The fact that hospitals frequently experienced stock outs was also found to have implications on their product portfolio management. As previously mentioned, central shortages and stock outs essentially moved the decoupling point for these antibiotics downstream. We argue that this makes the management of a broad product portfolio yet harder to manage, putting added strain on central capacity. We found it reasonable to assume that this burden would largely fall on ZAMMSA, as the rationing of antibiotics to facilities in these instances also would involve product management decisions that had to be made centrally, with little or limited assistance by product management capabilities from the hospital. The fact that ZAMMSA informants have pointed to SKU variation being an obstacle to efficient operations within the healthcare supply chain gives more credence to this belief.

5.1.2.3.2 Ordering

The literature reviewed in the frame of reference suggested that the inventory policy should be tailored to the objectives and the limitations of the supply chain. For instance, high reorder points strengthen the system's robustness but increase the cost and capacity strain of holding a large inventory, while the opposite renders the system more cost-efficient at the expense of a higher stock out risk. The empirical data suggested that at Zambian tertiary hospitals, orders not being delivered in time nor in full quantity made the reorder points insufficiently high to address stock outs. This in turn led to hospitals being more reliant on emergency ordering to ensure availability. A similar balance has to be ensured with regards to the quantity in which orders are placed. Large order quantities allow for utilising economies of scale in distribution but increase holding costs, while low quantities reduce the need for storage capacity at the warehouse to which the replenishment order is delivered. The empirical data gave evidence to the notion that the limited order-processing capacity at the central warehousing paired with the limited delivery capacity imposed limitations on how often orders could be expedited. Therefore, an increase in order frequency would be to no avail, as long as distribution frequency would remain the same. We argue that this reduces the system's resilience to disruptions. The lack of storage capacity at hospitals further complicates the issue further, as long resupply intervals necessitate large order quantities, which in turn calls for higher inventory levels at the hospitals.

In the case of the Zambian healthcare supply chain, we also found that the lack of funding also greatly restricted the room for manoeuvre. While stock outs are generally deemed unacceptable in healthcare contexts as they risk jeopardizing the health of its patients, the cost of ensuring stock availability incurs substantial costs. In fact, Axsäter (2006) suggests that costs incurred are exponentially proportional to the level of availability. This can be viewed in light of the lack of funding to fundamental supply chain functions, such as procurement. The opportunity costs associated with guaranteeing availability in a distribution system with long resupply times can be immense. This entails that while investments in increased distribution and warehousing capacity at the central warehouse could enable tailoring the ordering system to more adequately meet the needs of hospitals, this could lead to resource starvation in other parts of the supply chain.

We also found that delayed order processes sometimes led to deliveries not being processed in due time to be included in the routine replenishment deliveries. As a consequence, hospitals risk running out of stock before the next replenishment is scheduled, resulting in them having to place emergency orders. While delayed ordering does not necessarily result in a stock out at the hospital(s) in question, the strain on distribution capacity and opportunity cost resulting from an increased use of emergency orders are likely to constitute an indirect cause of stock outs.

We had also expected bullwhip effects to lead to supply chain inefficiencies, and in the empirical data collection, we indeed found evidence that supported this notion; distorted demand signals would sometimes percolate upstream, becoming more and more variable, and as a consequence, difficult to manage. It was found that pharmacists sometimes placed additional orders when they did not trust that outstanding orders would be delivered. In literature, this is referred to as the Houlihan effect and is believed to cause a cascade effect of additional unsatisfactory deliveries. We argue that this pointed to a lack of inventory visibility and insufficient information-sharing between the actors in the supply chain. This is also supported by supply chain literature reviewed in the frame of reference. We encourage that future research is conducted to understand how well the systems for information sharing perform in Zambia. If inefficiencies are significant, the opportunity costs of insufficient information sharing could potentially be high. We furthermore argue that stock outs as a consequence of bullwhip effects can be avoided if upstream distribution decisions and decisions relating to inventory allocation are made in collaboration with pharmacists at the hospital.

5.1.2.3.3 Monitoring and Counting

We found that monitoring and counting at hospitals are foremostly performed as a support function to demand forecasting and ordering. The data monitored was found to mainly consist of issue data and inventory levels. We argue that the risk for stock outs would increase if the monitoring of either one of these two categories would be inadequately managed. If issue data used to calculate the hospital's demand is incorrectly monitored, the order quantities in the system will not match the actual demand. On one hand, inflated data may lead to bullwhip effects in the system, resulting in a buildup of stock at the decoupling point. On the other hand, if the issue data would capture underestimated demand, order quantities calculated by the eLMIS system would likely prove insufficient. If inventory levels are not monitored with enough scrutiny, we argue that depleted inventory levels risk not being detected in due time. We furthermore argue that this could lead to a compounding of emergency orders, and possibly, stock outs. Stock outs are particularly likely to occur if the replenishment lead times prove too long to restock the facility in time.

As inventory was counted exhaustively using a periodic-count method, spikes in the workload were experienced once a month, whenever the physical count took place. Another factor that was found to put strain on the monitoring capacity was the breadth of the product portfolio. Informants from both hospitals and ZAMMSA claimed that monitoring stock levels was made difficult by the large variety of commodities that they had to report on. This was found to be true both in terms of the number of different medicines that were stocked at the hospitals, and pack size variations. Moreover, pack sizes in use did oftentimes not correspond with the pack sizes defined in the eLMIS system. As a result, hospital pharmacists had to manually recalculate the suggested order quantities and convert these to pack sizes

defined in the system. This was recurrently found to result in incorrect order quantities. We argue that the reduced data quality caused by a lack of monitoring capacity at the hospitals was especially concerning considering that the long resupply interval rendered precise forecasts all the more important.

We found that the reason as to why consumption data was not used to calculate the demand for antibiotics was that inconsistencies in the reporting by facilities made it difficult to capture accurate consumption data at the hospitals. Interestingly, consumption data was successfully captured for medicines managed by the GHIs, for which it was stated that more robust reporting mechanisms had been implemented. We argue that this likely was the result of antibiotics not being regarded as a high-priority category of medicine. Furthermore, the empirical data provided evidence that the use of issue data resulted in less accurate forecasts, which was found leading to stock outs of antibiotics.

5.2. Addressing Antibiotic Stockouts through Inventory Management Strategies

This section discusses how inventory management concepts presented in the frame of reference can be applied to address the causes behind stock outs discussed in the previous section. While many root causes lie outside of the scope of the paper, the symptoms can nonetheless be addressed through inventory management strategies at tertiary hospitals. In this section the authors therefore discuss both remedies to supply chain shortcomings that transpire at tertiary hospitals, as well as mitigation strategies to ameliorate the impact of shortcomings upstream in the supply chain. Similar to the previous section, the analysis presented in this section builds knowledge necessary to answer research question two.

5.2.1 Product Portfolio Management and Classification

In the empirical data collection, and the analysis presented above, we identified several shortcomings that can be addressed through product portfolio management and classification. For instance, we found that the hospitals experienced that their operational needs were not fully mirrored by the product portfolio managed in the public healthcare system, that is, the Zambian essential medicines list. This raises the question of whether the essential medicines list ought to be extended. However, as hospitals are forced to procure medicines not listed on the essential medicines list themselves using their open procurement grant, we argue that a potential extension of the list also would entail centralising procurement for the medicines added.

A centralised procurement comes with several advantages. By giving one actor with end-to-end supply chain oversight responsibility of securing inbound supply, fragmented accountability can be counteracted. In Zambia, this was one of the reasons as to why procurement functions were transferred from the MoH to ZAMMSA. A centralised procurement agency naturally has greater procurement capabilities, allowing for the employment of advanced procurement strategies. By centralising procurement decisions to an actor with responsibility of securing sector wide availability, supply equity can be promoted together with a holistic approach to funding allocation. Yadav (2015) also suggests that it is easier to enforce unified quality standards in a centralised procurement system and that the increased purchasing power of a centralised procurement agency buying in bulk may lead to lower medicine prices. Additionally, we argue

that since central procurement agencies often manage a well-established supplier base they are able to procure new medicine through already established channels. However, centralisation is not a panacea for all shortcomings in procurement, and both previous research and the empirical data pointed towards several potentially adverse effects.

The empirical data suggested that the national procurement of medicines in Zambia was crippled by an accumulation of supplier debt. Moreover, the failure to pay suppliers was found leading to contract breaches and payment defaults. Barbosa and Fiuza (2011) suggests that nations unable to fulfill the payment terms stated in the contract often are forced to pay higher prices due to the increased credit risk of the suppliers. The empirical data did not provide any insights as to the financial situation of tertiary hospitals, but we suggest that this should be taken into consideration when deciding on a potential extension of the essential medicines list. Furthermore, we argue that while ZAMMSA have a holistic view of the supply chain, the hospitals most likely have a better understanding of their own operational needs. Moreover, concerns have been raised concerning procurement in the Zambian public healthcare sector being reactive rather than proactive, resulting in an untimely disbursement of funds and long lead times. Yadav (2015) suggests that decentralising the procurement could increase the speed and flexibility of purchasing, somewhat mitigating this issue. Furthermore, Yadav (2015) also suggests that the increased competition resulting from an increased level of decentralisation could increase the incentive for improvements in the procurement function. However, it shall be noted that if the budget allocation for the hospitals' open procurement grant remains the same, so would the percentage of purchases performed without involving the central procurement agency. While the empirical evidence did not establish which drugs the open procurement grant would be reallocated to after an update of the essential medicines list, we found it reasonable to assume that the hospitals would allocate a larger share of the grant to medicines that are also provided by ZAMMSA. This would, in turn, imply a greater degree of competition for these medicines.

Further complicating matters, it was maintained by the ZAMMSA informants interviewed that it was already difficult managing the ample product portfolio. As previously discussed, extending the essential medicine list entails expanding the product portfolio managed by ZAMMSA. We argue that this may lead to increased supply chain complexity, an amplified capacity strain on central warehousing processes and escalated inventory handling costs in ZAMMSA's operations. Therefore, we underline that these adverse effects of extending the product portfolio must be considered. If the essential medicine list is to be extended, we suggest that collecting inputs from hospital staff, both those working with medicine procurement and prescription would be key to ensure that the medicines deemed most important for the hospitals' operations are added without excessively increasing the supply chain complexity. While we have identified that there are possible benefits and trade-offs to extending the essential medicine list, our empirical data provides too weak evidence to draw definitive conclusions.

In the empirical data collection, we found evidence suggesting that orders based on estimates frequently resulted in over- or under-ordering. Furthermore, the estimates frequently led to distorted demand signals being conveyed upstream, giving rise to bullwhip effects. We furthermore found that the reason why estimates were used in place of counts could likely be attributed to capacity constraints at the hospital pharmacy. As a consequence, pharmacists did sometimes not have sufficient resources to perform inventory counts for all product categories, with the unintentional consequence that some counts were

replaced by estimates. Literature reviewed in the frame of reference suggests that there are potential efficiency gains that can be enjoyed if product classification is implemented at the hospital pharmacy. More specifically, Vila-Parrish and Ivy (2013) suggest that a strategic classification of healthcare products serves the purpose of focusing hospitals' limited resources to prioritised areas, ensuring a high output-to-input ratio. As such, we analysed the potential benefits of implementing product classification at tertiary hospital pharmacies in a Zambian context.

As previously mentioned, the classification of products is a widely used and recognised tool to increase the efficiency of the inventory management and to encompass a wide array of product characteristics into one inventory management system without making it too complex to handle. With regard to this, we found that the healthcare items in the Zambian healthcare supply chains were indeed classified already to some extent. However, classification was solely based on whether commodities were listed on the Zambian essential medicine list or not, and to what disease-specific program it belonged to. The empirical data study also indicated that product classification was already being conducted in an uncoded and nonsystematic fashion at hospital pharmacies. When faced with insurmountable inventory counts and insufficient resources, hospital pharmacists would sometimes prioritise counting some products, and make estimates for others. We found that the order of priority was decided by the hospital pharmacists based on their experience of critical, frequently prescribed, or frequently stocked out products. We argue that the uncoded practice stands to show that there is a demand for a method for prioritising monitoring and counting in an evidence-based manner.

There are many benefits with implementing a product classification that can enable tailored management of inventory. We found that the current product classes in Zambian hospitals mainly dictated how demand forecasting and procurement was performed for the commodities, placing less emphasis on the strategies used to manage them. In practice, this implied that high-volume items that were used in day-to-day operations were managed in the same way as those with an erratic, low-volume demand. In a supply chain burdened with lacking financial and operational resources such as the Zambian healthcare supply chain, ensuring a high output-to-input ratio is key. Therefore, we suggest that ABC classification could be a viable remedy to some of the capacity issues currently faced at the hospital. Based on the empirical data collection, we also assessed that it would be prudent to take into account any potential stock outs' consequences on the patients' health. As such, we argue that classification should also prioritise medicines based on to what extent unavailability of the medicine would affect the outcome of the patients' treatment. Therefore, we found that ABC-VED classification could be used to address both capacity issues at the hospital pharmacy, but also ensure that the most critical products remain available.

A study performed at a tertiary hospital in India showed that, when an ABC-VED analysis was used as a basis for item classification, only 21 percent of the SKUs belonged to category I, requiring maximum attention. This can be compared to the much larger 'maximum-attention category', essential medicines list, that was found to be used in Zambia. While all items listed in the essential medicines lists are indeed deemed essential, research shows that it is possible to further categorise medicines based on the criticality of stock outs. By further categorising the essential medicines into classes with varying degree of strategic importance, we hypothesise that capacity in inventory management processes could be alleviated while not jeopardising service provision in prioritised areas.

As suggested by Vila-Parrish and Ivy (2013), and outlined in table 2.4 in the frame of reference, the items with high consumption value should ideally be managed with low safety stocks, meticulous monitoring, and prioritised forecasting. However, this necessitates responsive deliveries for these products. Since this was not found to be viable given the current bimonthly distribution schedule, safety stocks and monitoring capacity should be set accordingly. Nevertheless, we also argue that the low safety stock suggested is mainly an important factor to consider if the ABC-classification is based on consumption value. This is because items with high consumption value incur high holding costs. If the ABC-classification is based on a different criterion, we argue that this would allow for a strategy where availability is secured through heightening reorder points instead of making resupply more frequent. To fully benefit from product classification, we therefore suggest that other design changes in the healthcare supply chain should be considered in parallel to ABC-VED classification. For the Zambian healthcare context, this would supposably entail: performing demand forecast and inventory counts more frequently through cycle counting, either shortening the resupply interval or heightening the reorder points for strategic products, and ensuring that several framework agreements with secured funding allocation allowing for good supplier relationships and a reduced risk of contract breaches. While the replenishment interval currently is set at the limit of what the central capacity can handle, moving the decoupling point for strategic items, inter alia A-class items could allow for reduced storage levels at the hospitals and a reduction in lead times. To the best of our knowledge, the stock-keeping strategy being developed for the regional hubs did not involve any proposed changes in distribution frequency. We suggest that an investigation of the potential benefits of increasing distribution frequency for prepositioned strategic items is an interesting topic for future research.

5.2.2 Ordering

In the empirical data collection, we found that stock outs could be explained to be the consequence of inventory policies not taking supply disruptions into account. While the configuration of the inventory policy, more specifically reorder points, would have adequately mitigated stock outs if orders were delivered on time and in full quantity, the lack of order fulfillment from the central warehouse resulted in the hospitals being heavily reliant on the use of emergency orders.

As a measure to address these identified shortcomings, we suggest that reorder points are increased for strategic items deemed critical for the treatments provided at the hospital. We considered the alternative strategy of increasing responsiveness in the external healthcare supply chain, by way of increased distribution frequency for strategic products, to be outside of the scope of this paper. The issue could also be remediated by increasing the reorder points for all products, but this would obviously incur a dramatic increase in inventory-holding costs in the form of tied up capital and excessive storage needs. This should be considered in light of the fact that both operating capacity and storage space were found to be limited in hospital pharmacies.

Maestre et al. (2018) suggest that storage capacity should be included as a balance constraint when configuring the inventory policies at hospitals. In light of this, we argue that in order to increase the reorder points for some products, capacity would have to be released by lowering the reorder points for others. This points to potential synergies with an implementation of product classification. We suggest that ABC-VED analysis could be used to identify suitable candidates for strategic and non-strategic products respectively. We encourage future research to study the possible trade-offs in such a setup.

We also considered the caveat that increased reorder points for strategic items would naturally imply a greater risk of expiries. While previous research pointed to expiries being a minor issue it is not unreasonable to assume that, if safety stocks for strategic items at healthcare facilities should dramatically increase, an elevated percentage of expiries would raise concerns.

5.2.3 Monitoring and Counting

The discrepancies between the digital stock levels and the physical inventory caused by estimates replacing physical stock counts were thought to have great implications for the demand forecasting and order patterns. This was believed to cause inflated orders and bullwhip effects, resulting in ineffective ordering and an accumulation of stock at the central warehouse. Additionally, emergency orders placed due to sudden discoveries of unexpectedly low inventory levels were found to disturb the routine distribution schedule. Research suggests that this could be attributed to the periodic review method used for counting, in which the inventory is counted exhaustively every time. Axsäter (2006), suggested that this could be mitigated by implementing some sort of cycle count method. If a cycle count method was to be implemented at Zambian hospitals, it would necessitate deciding upon a selection criterion.

When deciding on what cycle-count method to implement, there are several advantages and disadvantages that need to be considered. A location-based cycle counting method would serve the purpose of being easy to implement, with the perk of flattening the spikes in the workload to a more manageable level. Gumrukcu et al. (2008) suggested that opportunity-based cycle counting could prove effective in reducing the overall workload of counting, especially if implemented for high-cost, slow moving items. However, we would caution that this would likely imply a drastic change from how counting was currently being performed. We therefore argue that this could risk leading to a lack of adherence with SOPs, with the unwanted short-term effect that data quality would be negatively affected.

Another alternative that we considered was implementing an ABC-cycle count method, where strategic inventory is counted more frequently. There are several possible criteria to base the ABC-analysis upon, such as the value, volume or velocity of the SKUs. We suggest that this is done in parallel to the classification for the product. We contrived that a pragmatic solution for implementing ABC-cycle counting would be to piggyback on the regional hubs' stock-keeping strategy that is currently being developed. In this plan, items will be classified based on their velocity, i.e. how often they are ordered, with items of high velocity being staged at the hubs. We argue that there are potential synergy effects to benefit from in such an arrangement. For example, we find it likely that the items selected for storage at the regional hubs are items that are frequently subject to emergency orders. The same items are also likely beneficial to prioritise in an ABC-cycle count method as their inventory would often fall below critical levels.

Implementing a cycle count method could also increase the adherence of inventory management SOPs at hospitals, considering that there were reports of hospital pharmacists already practicing a sort of ad-hoc product classification to decide on where to allocate their limited monitoring capacity. This has likely resulted in the system consistently regarding inventory levels for these items as ascertained as for

prioritised items. If institutionalised, the increased inventory-level uncertainty for non-strategic products as an effect of the longer review periods could be calculated and accounted for in inventory management strategies. Therefore, we argue that a cycle-count method would make monitoring and counting more evidence based.

As with the previous inventory management strategies proposed, we argue that there are synergy effects to be enjoyed if monitoring and counting incorporates ABC-VED analysis. We argue that more robust reporting mechanisms should be implemented to allow for the use of consumption instead of issue data to calculate demand for antibiotics. As this could lead to an increased strain on the monitoring capacity, we suggest that this should be implemented primarily for products that are classified as strategic products. Furthermore, for high-consumption value items, we argue that consumption ideally should be monitored and reported on a regular basis. This would likely lead to increased forecast accuracy for these products. In fact, previous research has found that an increase in frequency by which consumption is reviewed has considerable effect on how well healthcare supply chains can cope with emergency demand spikes. We suggest that capacity for the increased focus on strategic products can be reallocated from the monitoring processes for items of moderate and little strategic importance. Vila-Parrish and Ivy (2013) supports the notion that non-strategic items to a large extent can be based on historical data or estimates.

6. Conclusions

This section emanates from the analysis presented in the previous section. Based on the discussion and ideas covered in the analysis, we draw conclusions to fulfill the aim of the study. This section presents a summary of results, answers to the research questions, the research contribution, study limitations, and suggestions for future research.

6.1 Summary of Results

To summarise the results, we have drawn the conclusions that antibiotic stock outs at tertiary hospitals can be explained by considering the healthcare supply chain context and healthcare supply chain strategies employed in Zambia. The study has illustrated that many stock outs can not exclusively be attributed directly to specific shortcomings. Rather, general inefficiencies and strategic misalignments in the healthcare supply chain in Zambia are part of a greater picture that altogether can explain antibiotic stock outs. In a system subject to resource scarcity, we have found that opportunity costs are highly relevant; cost reduction for one activity entails that funds can be redistributed to the procurement of antibiotics that are currently not procured in the quantities demanded. Furthermore, the study did not only arrive at results that were isolated to antibiotics specifically, but rather pointed to the need for effectivisation measures in the general healthcare supply chain in Zambia. While this can appear to be a deviation from the focus on antibiotics, we found that the antibiotic supply chain was largely intertwined with that of other therapeutic areas in Zambia, and that performance improvements in the general healthcare supply chain had the potential to increase antibiotic availability at tertiary hospitals.

Nota bene, the findings did not only point to shortcomings in the healthcare supply chain. However, the nature of the research questions, and accordingly the method, naturally generated findings that would pinpoint any possible supply chain deficiencies. In light of this, we underline that we also identified some best practices. For example, our findings suggested that the recently implemented pipeline management program had effectively mitigated supply spikes and congestion in the central warehouse, by way of enhancing supplier coordination. The roll-out of the nation-wide eLMIS system was also found to be an effective measure to increase information sharing and inventory visibility. We also determined this to be an important prerequisite for the functioning of the centralised order-processing system. Additionally, our findings also pointed to the potential benefits of prepositioning strategic stock at the regional hubs, which is why we also endorse the planned development of this program in the future. As a final remark hereof, we highlight that the study findings should be interpreted in light of the financial and capacity limitations imposed on actors in the Zambian healthcare system, acknowledging the challenges faced in pursuing excellence in an under-funded context.

Our results indicated that stock outs to some extent could be remediated via inventory management strategies at tertiary hospitals. By considering the potential benefits of ABC-VED classification, effectivisation of counting, strengthened reporting capabilities, and heightened reorder points for strategic products, we generated hypotheses as to how stock outs can be mitigated in absolute numbers, but also minimised for critical antibiotics.

With that said, we note that the findings indicate that the issue of antibiotic stock outs can not solely be resolved at hospital level. The results stand to show that ineffective procurement will perpetuate the issue of stock outs as long as the total inbound supply of antibiotics remains smaller than the demand at hospitals. To this end, inventory management strategies at tertiary hospitals can only do so much. We therefore encourage that future research is conducted to understand how antibiotic stock outs can be addressed on a central or even multilateral level. In this regard, our findings suggest several topics for future research, inter alia procurement pooling, and the investigation of how antibiotic availability as an issue can be placed on the global agenda and integrated in GHIs.

6.2 Answering Research Question One

RQ1: *Why do stock outs occur at tertiary hospitals in Zambia?*

The study identified several shortcomings in the Zambian healthcare supply chain that explained the occurrence of stock outs at tertiary hospitals in Zambia. The main cause of stock outs identified was, as anticipated, that the Zambian healthcare system was insufficiently funded. Resource scarcity did not only imply that the drugs procured did not meet the demand for drugs at the tertiary hospitals, but it was also found to permeate and impose capacity constraints on other processes in the supply chain. In addition to insufficient funding, the main causes of antibiotic stock outs identified in the study are outlined below.

Ineffective procurement

We found that ineffective procurement contributed to stock outs at tertiary hospitals. There were several issues that rendered procurement ineffective. First of all, the funding gap for procurement of antibiotics resulted in lower quantities being procured than necessary to ensure availability throughout the supply chain. Second of all, procurement was also rendered ineffective by untimely disbursements of funds to procure healthcare commodities; funds were often disbursed in response to emergencies instead of proactively.

It was found that procurement of antibiotics was obscured by an imbalanced allocation of funds between commodity categories, where antibiotics were found to be a financially neglected therapeutic area as compared to those managed by GHIs. Moreover, the reliance on few suppliers was found to lead to elevated procurement prices, and exposure to disruptions in the global pharmaceutical supply chain. Affordable and timely procurement was also impeded by the Zambian debt burden as well as the depreciation of the local currency. The latter affected the purchasing power vis-a-vis the global pharmaceutical suppliers, with whom contracts were signed in USD.

Insufficient Order-Processing and Distribution Capacity

We found that insufficient order-processing and distribution capacity at the central warehouse resulted in long resupply lead times and frequently delayed deliveries. This, in turn, was found to increase the hospitals' reliance on emergency orders to prevent stock outs. The lack of capacity could to some extent be attributed to an excessive focus on procurement and more politically attractive investments as opposed to strengthening operations in the supply chain. Erratic supply and frequent stockouts at the central warehouse complicated distribution scheduling and put further strain on the limited capacity, as supply

had to be disseminated to the hospitals whenever it trickled in. This was further aggravated by the increased influx and erraticity of Covid-19 supplies.

Non-Effective Inventory Policies with regard to Supply Chain Disruptions
The configurations of the inventory policies at tertiary hospitals were found insufficient to accomodate for the fact that orders often were not being delivered in time nor in full quantity. This resulted in the hospitals becoming more reliant on emergency orders to prevent stock outs. Also, it was found that if the shortcomings regarding the order fulfillment were to be resolved, the storage space at the hospital pharmacies would prove insufficient. All the aforementioned points towards the inventory policies not being configured with the shortcomings and capacity limitations of the supply chain in mind.

Inaccurate Input Data for Forecasting
The study found that inaccurate forecasts led to inadequate antibiotic replenishments to the hospital pharmacies. The shortcomings in the forecasts could mainly be attributed to poor quality of the data used in the quantification process. This was found to be the consequence of two phenomena.

First of all, limited monitoring and counting capacity at hospital pharmacies resulted in inaccurate reporting of current inventory levels and antibiotic consumption. This was aggravated by a large variation in products and pack sizes that was time consuming to manage.

Second of all, the data used for demand forecasting for antibiotics was found to not accurately reflect actual demand. As issue data was used as a proxy for demand, repeated or prolonged antibiotic stock outs incited a negative feedback loop in which the issue data falsely indicated decreases in demand, resulting in inadequate replenishments with respect to actual demand.

6.3 Answering Research Question Two

RQ2: *How can stock outs of antibiotics at tertiary hospitals be addressed through inventory management strategies?*

Our results indicated that stock outs to some extent could be remediated via inventory management strategies at tertiary hospitals. In light of the causes of stock outs identified, we considered the current inventory management strategies employed at tertiary hospitals in Zambia on the basis of inventory management literature. This emanated in hypotheses for how stock outs could be mitigated in absolute numbers, but also minimised for antibiotics critical for service provision. The hypotheses are stated below.

Stock outs could to be remediated by further classifying essential medicines
ABC-VED classification can be an effective way to increase the output-to-input ratio of the hospitals' limited resources and can increase the availability of strategic products. By further classifying the essential medicines into different classes, we hypothesise that capacity in inventory management processes could be alleviated while not jeopardising service provision in prioritised areas.

Stock outs could to be remediated by enhancing reporting capabilities for antibiotic consumption
Enhanced reporting capabilities for the reporting of consumption of antibiotics would allow for consumption data being used instead of issue data when calculating the demand for antibiotics. This would lead to more accurate forecasting, which in turn would reduce the risk of stock outs occurring at the hospitals.

Stock outs could to be remediated by implementing cycle counting
Implementation of ABC-cycle counting would even out the spikes in workload at the hospital pharmacies, increase adherence to SOPs and enable optimisation of the allocation of monitoring capacity.

Stock outs could to be remediated by heightening the reorder point for strategic products
Heightening reorder points for strategic products reduces the risk of stock outs of these products. We hypothesize that this could be implemented without increasing the need for capacity if reorder points for non-strategic items are lowered.

6.4 Contribution

This section presents the research contributions to theory and practice respectively.

6.4.1 Contributions to Theory

While previous research has been conducted on how inventory management strategies can be applied in healthcare systems to improve service provision and reduce costs, we found the body of literature far slimmer with respect to academic research conducted in LMICs. Instead, most sources found comprised grey literature such as government reports, policy notes and project evaluations reports from implementing partners. In addition to this, recent and fundamental supply chain reforms have rendered most of the previous research conducted in Zambia obsolete. According to Cloutier and Langley (2020 p.6), to contribute to theory by answering a narrative "why" research question, previous research and theories are connected with empirical evidence to provide *"a set of predictive regularities in the form of testable propositions that hang together as a whole"*. We argue that by connecting inventory management literature to this relatively unexplored context, and by displaying the methods used to arrive at our conclusions, we can form testable propositions on which to build further research.

Furthermore, Boer et al. (2015) argue that research can contribute to theory by following a contingency approach. In a contingency approach, theoretical contribution is ensured by identifying and analysing contextual factors that influence the relationships between dependent and independent variables. By investigating how contextual factors in the Zambian public healthcare supply chain influenced how inventory management strategies could be employed at tertiary hospitals to prevent stock outs, we believe to have made a contribution to theory. To the best of our knowledge, no previous academic research has been conducted on this relationship.

6.4.2 Contribution to Practice and Organisation

A lack of antibiotic availability is crippling the Zambian healthcare system and hindering tertiary hospitals from providing effective, cost-efficient care to its patients. While the Zambian healthcare supply

chain has undergone major changes in recent times, the issue of antibiotic availability remains. This calls for conducting research to understand how availability can be ensured in light of the Zambian healthcare supply chain context. We argue that by identifying bottlenecks in the healthcare supply chain, this report could act as a basis for developing policies directed towards combating these shortcomings. The suggested implementation of a product classification presented in this report could help improve capacity allocation and increase the input-to-output ratio in tertiary hospital's inventory management operations, which we argue is a chief objective to the Zambian healthcare supply chain. We do however endorse conducting further research taking capacity and resource restraints into consideration before making any major changes to the supply chain.

Our hosting organisation ReAct aims at engaging the international community to act to halter the growing threat of antibiotic resistance. However, ReAct's action for change is twofold; limiting the excessive use of antibiotics must be promoted in parallel to simultaneously promoting health equity and the right to appropriate treatment. Making the matter even more complex, the two issues are interrelated; access to essential antibiotics is in large a prerequisite for coherent and effective regulation of the administration of ditto at point of service. In other words, a steady access of essential antibiotics can increase the potential for program impact at health facilities. Therefore, action on antibiotic resistance not only entails raising awareness, engaging stakeholders and influencing policy-making relating to the administration of antibiotics at point of service, but also safeguarding widespread access to antibiotics by improving the performance of the antibiotic supply chain. We believe that this report can prove useful to the work of ReAct in several ways. First, by pointing at the relative lack of financial commitment to antibiotics, we hope to spark discussions on how funding for antibiotics could be secured to prevent stock outs. Second, a prerequisite for rational prescription of antibiotics is ensuring availability of an adequate arsenal of antibiotic drugs at the disposal of health practitioners. By generating hypotheses regarding how shortcomings in the healthcare supply chain and hospital operations result in antibiotic unavailability, the report provides insights feeding into ReAct's work of developing and implementing national action plans for the coordinated response to AMR in Zambia.

6.5 Limitations

There were some limitations to the research findings as a consequence of the research scope and research questions. Due to the fact that the study concerned itself with generating hypotheses for possible remediation strategies strictly within the domain of inventory management at hospitals, the scope of influence for these remediation strategies was somewhat limited. For example, we found that inventory management strategies at tertiary hospitals in Zambia had little effect on stock out causes upstream in the supply chain, such as ineffective procurement or exposure to disruption risks.

We furthermore recognise that a significant limitation to our research was that data saturation was not achieved in the interview study. While this was managed by way of triangulation with secondary data sources, it still accounts for a limitation as to the validity and representativeness of insights obtained from informants.

Some of the limitations to the study were confounded by the upsurge of the Covid-19 pandemic. Due to the Covid-19 pandemic, we were unable to make on-sight visits at the tertiary hospitals and ZAMMSA

facilities investigated. Observing actual practice holds a clear advantage in conducting case studies and would have strengthened our findings. A propos the pandemic, we also acknowledge that it is possible that implications of the pandemic response in Zambia comprised variables extraneous to the investigation. As such, we highlight that some of the findings may not reflect the healthcare supply chain in Zambia in general, so much as they reflect the healthcare supply chain in Zambia during the Covid-19 pandemic.

It is also possible that researcher bias has affected the outcome of the study. While not done intentionally, conducting semi-structured interviews in which deviations from the interview guides are allowed may have exposed the study to the risk of encouraging answers that were in line with our own preconceptions and interests.

6.6 Future Research

As a first suggestion for future research, we would like to point towards the need to increase the validity of the findings in this report. In order to attend to the relatively small sample of interviewed informants, we suggest that future research is conducted on the same units of observation, but with a larger sample of informants, to confirm the findings from the primary data collection.

Explanatory research was conducted in order to answer research question one and identify the causes of stock outs. This necessitates a high degree of internal validity for the findings. To increase internal validity, we encourage that further research is conducted to validate the findings. We would encourage this research to be conducted by way of quantitative methods or simulation.

The hypotheses to how stock outs can be addressed through inventory management strategy at tertiary hospitals were generated through exploratory research, implying that confirmatory research is needed to establish the strength of the findings. We encourage future research to review and examine our findings with scrutiny, to validate our findings, and confirm our hypotheses. Furthermore, since most of the hypotheses generated for research question two included the implementation of some sort of product classification, we suggest that this is an interesting topic for future research. More specifically, we recommend future research to determine suitable criteria on which to base the classification, and what the possible trade-offs implementing such a setup would be.

Beyond the need for validating and building on the findings of this report, we came across several interesting topics for future research that were deemed outside the scope of the study. These are outlined below.

We found that the potential to mitigate stock outs through inventory management strategies at tertiary hospitals is limited, as most stock outs result from shortcomings in the upstream supply chain. A major finding was the strategic misalignment between how the supply chain was designed to function and how it functioned in practice. Future research could possibly be directed at evaluating the trade-offs between opting for a pivotal approach, where the strategic foundation is adapted to the shortcomings of the supply chain, or an incremental approach, where the configurations of the inventory management functions are adapted to cope with the current misalignment. We also found indications that the configuration of the supply chain rendered more advanced healthcare-providing facilities more reliant on emergency orders to

mitigate stock outs. In light of this, we encourage future research to be conducted on the potential trade-offs associated with tailoring settings for the distribution schedule and inventory policies at the expense of collapsed supply chain standardisation.

Furthermore, the empirical data pointed towards stock outs affecting prescription patterns. For example, antibiotic stock outs were found to affect the demand not only for the antibiotic stocked out, but also of substitute and complementary drugs. We suggest that these co-dependencies could be analysed with greater scrutiny, possibly by analysing antibiotic consumption data in conjunction with antibiotic availability data at the hospitals. The empirical data gave us reason to believe that the diagnostic uncertainty caused by an unavailability of laboratory reagents resulted in an increased use of broad-spectrum antibiotics. We believe that this possible correlation also could be examined by analysing antibiotic consumption data in conjunction with availability data for laboratory reagents.

Lastly, we believe that the issue of antibiotic availability has to be discussed on a multilateral level. In this regard, we suggest that procurement pooling and the investigation of how antibiotic availability can be placed on the global agenda, and integrated in GHIs, constitutes interesting topics for future research.

7. References

African Development Bank Group., 2021. Zambia Economic Outlook. [online] African Development Bank - Building today, a better Africa tomorrow. Available at: <https://www.afdb.org/en/countries-southern-africa-zambia/zambia-economic-outlook> [Accessed 20 May 2021].

Ambrosino, D. and Grazia Scutellà, M., 2005. *Distribution network design: New problems and related models. European Journal of Operational Research*, 165(3), pp.610-624.

Anupindi, R., Dada, M. and Gupta, S., 1998. Estimation of Consumer Demand with Stock-Out Based Substitution: An Application to Vending Machine Products. *Marketing Science*, 17(4), pp.406-423.

Arney, L., Yadav, P., Miller, R. and Wilkerson, T., 2014. Strategic contracting practices to improve procurement of health commodities. *Global Health: Science and Practice*, 2(3), pp.295-306.

Avis, M., 2006. Valid arguments? A consideration of the concept of validity in establishing the credibility of research findings. *Journal of Advanced Nursing*, 22(6), pp.1203-1209.

Axios International, Inc., 2017. Zambia National Supply Chain Assessment Report: Capability and Performance. Submitted to the United States Agency for International Development by Axios International, Inc., under USAID Contract Number: AID-OAA-TO-16-0013 - USAID Global Health Supply Chain – Technical Assistance NSCA Task Order.

Axsäter, S., 2006. Inventory Control. 2nd ed. Lund: Springer Science+Business Media, LLC

Banin, E., Hughes, D. and Kuipers, O., 2017. Editorial: Bacterial pathogens, antibiotics and antibiotic resistance. *FEMS Microbiology Reviews*, 41(3), pp.450-452.

Barbosa, K. and E. Fiuza, 2011. Demand aggregation and credit risk effects in pooled procurement: evidence from the Brazilian public purchases of pharmaceuticals and medical supplies. FGV-EESP C-Micro Working Paper July(299): 1-49

Bass, J., Beecham, S. and Noll, J., 2018. Experience of industry case studies. *Proceedings of the 6th International Workshop on Conducting Empirical Studies in Industry*,.

Bazargani, Y., Ewen, M., de Boer, A., Leufkens, H. and Mantel-Teeuwisse, A., 2014. Essential Medicines Are More Available than Other Medicines around the Globe. *PLoS ONE*, 9(2), p.e87576.

Bennett, N., Glatter, R. and Levašič, R., 1994. Improving educational management through research and consultancy. London: A SAGE Publications Company, pp.135-136.

Benrqya, Y., Estampe, D., Vallespir, B. and Babai, M., 2014. Impact of Product Characteristics on Distribution Strategy Selection. *Supply Chain Forum: An International Journal*, 15(3), pp.38-50.

Bertaux, D., 1981. Biography and Society: The Life History Approach in the Social Sciences. London: Sage, p.37.

Bhattacharya, B., Lin, L., Batta, R. and Ram, P., 2019. Stock-out severity index: tool for evaluating inequity in drug stock-outs. *Central European Journal of Operations Research*, 28(4), pp.1243-1263.

Bhattacharya, B., Lin, L., Batta, R. and Ram, P., 2019. Stock-out severity index: tool for evaluating inequity in drug stock-outs. *Central European Journal of Operations Research*, 28(4), pp.1243-1263.

Biesma, R., Brugha, R., Harmer, A., Walsh, A., Spicer, N. and Walt, G., 2009. The effects of global health initiatives on country health systems: a review of the evidence from HIV/AIDS control. *Health Policy and Planning*, 24(4), pp.239-252.

Bijvank, M. and Vis, I., 2012. Inventory control for point-of-use locations in hospitals. *Journal of the Operational Research Society*, 63(4), pp.497-510.

Birhanu, D., Lanka, K. and Rao, A., 2014. A Survey of Classifications in Supply Chain Strategies. *Procedia Engineering*, 97, pp.2289-2297.

Blackstone, A., 2012. Principles of sociological inquiry. Saylor Academy.

Boer, H., Holweg, M., Kilduff, M., Pagell, M., Schmenner, R. and Voss, C., 2015. Making a meaningful contribution to theory. *International Journal of Operations & Production Management*, 35(9), pp.1231-1252.

Bradley, J. and Arntzen, B., 1999. The Simultaneous Planning of Production, Capacity, and Inventory in Seasonal Demand Environments. *Operations Research*, 47(6), pp.795-806.

Broom, J. and Broom, A., 2018. Guideline relevance, diagnostic uncertainty, fear and hierarchy: Intersecting barriers to antibiotic optimization in respiratory infections. *Respirology*, 23(8), pp.733-734.

Bvuchete, M., Saartjie Grobbelaar, S. and Van Eeden, J., 2020. Best Practices for Demand-Driven Supply Chain Management in Public Healthcare Sector: A Systematic Literature Review. *South African Journal of Industrial Engineering*, 31(2), pp.11-27.

Byrnes, J., 2004. Fixing the healthcare supply chain. Harvard Business School Working Knowledge. Available at: http://hbswk.hbs.edu/archive/4036.html (accessed 21 April 2021).

CHUNG, W., 2009. The Roles of Distributor in the Supply Chain–Push-pull boundary. *International Journal of Business and Management*, 3(7).

Cameron, A., Ewen, M., Ross-Degnan, D., Ball, D. and Laing, R., 2009. Medicine prices, availability, and affordability in 36 developing and middle-income countries: a secondary analysis. *The Lancet*, 373(9659), pp.240-249.

Cameron, A., Ewen, M., Ross-Degnan, D., Ball, D. and Laing, R., 2009. Medicine prices, availability, and affordability in 36 developing and middle-income countries: a secondary analysis. *The Lancet*, 373(9659), pp.240-249.

Campuzano, F. and Mula, J., 2011. Supply Chain Simulation - A System Dynamics Approach for Improving Performance. *Springer Science+Business*, London

Caniëls, M. and Gelderman, C., 2007. Power and interdependence in buyer supplier relationships: A purchasing portfolio approach. *Industrial Marketing Management,* 36(2), pp.219-229.

Carbonneau, R., Laframboise, K. and Vahidov, R., 2008. Application of machine learning techniques for supply chain demand forecasting. *European Journal of Operational Research*, 184(3), pp.1140-1154.

Center for Global Development, 2021. Pooled procurement of drugs in low and middle income countries. *European Economic Review,* 132, p.103655.

Chandra, C., & Kachhal, S. K., 2004. Managing health care supply chain: Trends, issues and solutions from a logistics perspective. *Paper presented at the Annual Society of Health Systems Management Engineering Forum,* Orlando FL.

Chanpuypetch, W. and Kritchanchai, D., 2018. A Process Reference Model for Hospital Supply Chain of Pharmaceutical Products. *Industrial Engineering & Management Systems*, 17(1), pp.43-61.

Cloutier, C. and Langley, A., 2020. What Makes a Process Theoretical Contribution?. *Organization Theory*, 1(1)

Cogan, D., Karrar, K., Jayasree K. Iyer., 2018. Shortages Stockouts and Scarcity - The issues facing the security of antibiotic supply and the role for pharmaceutical companies[White paper]. Access to medicine foundation.

Conlon, C. and Mortimer, J., 2013. Demand Estimation Under Incomplete Product Availability. *American Economic Journal: Microeconomics*, 5(4), pp.1-30.

DeCarlo, M., 2019. Scientific Inquiry in Social Work. n.p.

Denscombe, M. (2017). The good research guide: For small-scale social research projects. 6th edition. Maidenhead: Open University Press.

Dill, S. and Ahn, J., 2014. Drug shortages in developed countries—reasons, therapeutic consequences, and handling. *European Journal of Clinical Pharmacology,* 70(12), pp.1405-1412.

Dooley, L., 2002. Case Study Research and Theory Building. *Advances in Developing Human Resources*, 4(3), pp.335-354.

Doubova, S., Reyes-Morales, H., Torres-Arreola, L. and Suárez-Ortega, M., 2007. Potential drug-drug and drug-disease interactions in prescriptions for ambulatory patients over 50 years of age in family medicine clinics in Mexico City. *BMC Health Services Research,* 7(1).

Du, J. and Evans, N., 2011. Academic Users' Information Searching on Research Topics: Characteristics of Research Tasks and Search Strategies. *The Journal of Academic Librarianship*, 37(4), pp.299-306.

Dubois, A. and Pedersen, A., 2002. Why relationships do not fit into purchasing portfolio models—a comparison between the portfolio and industrial network approaches. *European Journal of Purchasing & Supply Management*, 8(1), pp.35-42.

Duclos LK (1993) Hospital inventory management for emergency demand. *Journal of Supply Chain Management* 29(4):30–37

Eisenhardt, K. and Graebner, M., 2007. Theory Building From Cases: Opportunities And Challenges. *Academy of Management Journal*, 50(1), pp.25-32.

Eisenhardt, K., 1989. Building Theories from Case Study Research. *Academy of Management Review*, 14(4), pp.532-550.

Farrelly, P., 2013. Choosing the right method for a qualitative study. *British Journal of School Nursing*, 8(2), pp.93-95.

Fonseca, L. and Azevedo, A., 2020. COVID- 19: outcomes for Global Supply Chains. *Management & Marketing. Challenges for the Knowledge Society*, 15(s1), pp.424-438.

GARDP., 2019. Delivering on the sustainable access of antibiotics: moving from principles to practice workshop report

Gammelgaard, B. and Flint, D., 2012. Qualitative research in logistics and supply chain management: beyond the justification for using qualitative methods. *International Journal of Physical Distribution & Logistics Management*, 42(8/9).

Gebicki, M., Mooney, E., Chen, S. and Mazur, L., 2013. Evaluation of hospital medication inventory policies. *Health Care Management Science*, 17(3), pp.215-229.

Golicic, S., Davis, D. and McCarthy, T., 2005. A Balanced Approach to Research in Supply Chain Management. *Research Methodologies in Supply Chain Management*, pp.15-29.

Govindaraj, Ramesh; Herbst, Christopher H.. 2010. Applying Market Mechanisms to Central Medical Stores: *Experiences from Burkina Faso, Cameroon, and Senegal. Health, Nutrition and Population (HNP) discussion paper;*. World Bank, Washington, DC.

Grünbaum, N., 2007. Identification of ambiguity in the case study research typology: what is a unit of analysis?. *Qualitative Market Research: An International Journal*, 10(1), pp.78-97.

Guest, G., Bunce, A. and Johnson, L., 2006. How Many Interviews Are Enough?. *Field Methods*, 18(1), pp.59-82.

Gumrukcu, S., Rossetti, M. and Buyurgan, N., 2008. Quantifying the costs of cycle counting in a two-echelon supply chain with multiple items. *International Journal of Production Economics*, 116(2), pp.263-274.

Halcomb, E. and Davidson, P., 2006. Is verbatim transcription of interview data always necessary?. *Applied Nursing Research*, 19(1), pp.38-42.

Hartono, E., Li, X., Na, K. & Simpson, J. 2010. 'The role of the quality of shared information in inter organisational systems use', *International Journal of Information Management*, 30(5): 399-407.

Heiskanen, K., Ahonen, R., Kanerva, R., Karttunen, P. and Timonen, J., 2017. The reasons behind medicine shortages from the perspective of pharmaceutical companies and pharmaceutical wholesalers in Finland. *PLOS ONE*, 12(6), p.e0179479.

Henry, C. and Foss, L., 2015. Case sensitive? A review of the literature on the use of case method in entrepreneurship research. *International Journal of Entrepreneurial Behavior & Research*, 21(3), pp.389-409.

Hinde, S. and Spackman, E., 2014. Bidirectional Citation Searching to Completion: An Exploration of Literature Searching Methods. *PharmacoEconomics*, 33(1), pp.5-11.

Houlihan, J., 1985. International Supply Chain Management. *International Journal of Physical Distribution & Materials Management*, 15(1), pp.22-38.

Huff-Rousselle, M., 2012. The logical underpinnings and benefits of pooled pharmaceutical procurement: A pragmatic role for our public institutions?. *Social Science & Medicine*, 75(9), pp.1572-1580.

Höst, M., Regnell, B. & Runesson, P., 2006. Att genomföra examensarbete. Lund: Studentlitteratur

International Monetary Fund (2019), "ZAMBIA 2019 Article IV Consultation—Press Release", Staff Report: Country Report No. 19/263, Washington: International Monetary Fund. Accessible at: https://www.imf.org/~/media/Files/Publications/CR/2019/1ZMBEA2019002.ashx

Jonsson, P. and Mattsson, S., 2017. Logistik: Läran om effektiva materialflöden. Johanneshov: MTM.

Kachali, L., Chimusoro, E., Karodia, A.M., 2014. An Evaluation of the Factors Influencing the Establishment of the Domestic Pharmaceutical Manufacturing Industry in Zambia. *International Journal of Accounting Research*, 1(12).

Kant, S., Haldar, P., Singh, A. and Kankaria, A., 2015. Inventory Management of Drugs at a Secondary Level Hospital Associated with Ballabgarh HDSS- An Experience from North India. *Journal of Young Pharmacists*, 7(2), pp.113-117.

Kanyakam, S., 2018. Inventory Management in Medical Stores of Secondary Care Unit Service Level Hospitals in Northeast of Thailand. *MAHASARAKHAM INTERNATIONAL JOURNAL OF ENGINEERING TECHNOLOGY*, VOL. 4, NO. 1

Khan, M., Meghani, A., Liverani, M., Roychowdhury, I. and Parkhurst, J., 2017. How do external donors influence national health policy processes? Experiences of domestic policy actors in Cambodia and Pakistan. *Health Policy and Planning*, 33(2), pp.215-223.

Kickbusch, I., 2011. Advancing the global health agenda. *UN Chronicle*, 48(4), pp.37-40.

Klug, F., 2006. Synchronised automotive logistics: an optimal mix of pull and push principles in automotive supply networks. *In: Logistics research network conference proceedings*. Newcastle University, pp. 187-191

Korstjens, I. and Moser, A., 2017. Series: Practical guidance to qualitative research. Part 4: Trustworthiness and publishing. *European Journal of General Practice*, 24(1), pp.120-124.

Kotzab, H., Müller, M., Reiner, G. and Seuring, S., 2005. Research Methodologies in Supply Chain Management. Heidelberg: Physica.

Kraiselburd, S. and Yadav, P., 2012. Supply Chains and Global Health: An Imperative for Bringing Operations Management Scholarship into Action. *Production and Operations Management*, 22(2), pp.377-381.

Kreng, V. and Chen, F., 2008. The benefits of a cross-docking delivery strategy: a supply chain collaboration approach. *Production Planning & Control*, 19(3), pp.229-241.

Kumar, S. and Chakravarty, A., 2015. ABC–VED analysis of expendable medical stores at a tertiary care hospital. *Medical Journal Armed Forces India*, 71(1), pp.24-27.

Kwon, I. and Kim, S., 2018. Framework for successful supply chain implementation in healthcare area from provider's prospective. *Asia Pacific Journal of Innovation and Entrepreneurship*, 12(2), pp.135-145.

Kwon, I. and Suh, T., 2004. Factors Affecting the Level of Trust and Commitment in Supply Chain Relationships. *The Journal of Supply Chain Management*, 40(2), pp.4-14.

Kwon, I., Kim, S. and Martin, D., 2016. Healthcare supply chain management; strategic areas for quality and financial improvement. *Technological Forecasting and Social Change*, 113, pp.422-428.

Kök, A. and Shang, K., 2014. Evaluation of cycle-count policies for supply chains with inventory inaccuracy and implications on RFID investments. *European Journal of Operational Research*, 237(1), pp.91-105.

Landry, S. and Beaulieu, M., 2013. The Challenges of Hospital Supply Chain Management, from Central Stores to Nursing Units. *Handbook of Healthcare Operations Management*, pp.465-482.

Larson, P. and Halldorsson, A., 2002. What is SCM? And, Where is It?. *The Journal of Supply Chain Management*, 38(4), pp.36-44.

Laxminarayan, R., Matsoso, P., Pant, S., Brower, C., Røttingen, J., Klugman, K. and Davies, S., 2016. Access to effective antimicrobials: a worldwide challenge. *The Lancet*, 387(10014), pp.168-175.

Leung, L., 2015. Validity, reliability, and generalizability in qualitative research. *Journal of Family Medicine and Primary Care*, 4(3), p.324.

Leung, N., Chen, A., Yadav, P. and Gallien, J., 2016. The Impact of Inventory Management on Stock-Outs of Essential Drugs in Sub-Saharan Africa: Secondary Analysis of a Field Experiment in Zambia. *PLOS ONE*, 11(5), p.e0156026.

Liu, L., Xu, H. and Zhu, S., 2020. Push versus pull: Inventory-lead time tradeoff for managing system variability. *European Journal of Operational Research*, 287(1), pp.119-132.

Lloyd-Jones, G., 2003. Design and Control Issues in Qualitative Case Study Research. *International Journal of Qualitative Methods*, 2(2), pp.33-42.

Lydon, P., Schreiber, B., Gasca, A., Dumolard, L., Urfer, D. and Senouci, K., 2017. Vaccine stockouts around the world: Are essential vaccines always available when needed?. *Vaccine*, *3*5(17), pp.2121-2126.

Ma, X., Vervoort, D., Reddy, C., Park, K. and Makasa, E., 2020. Emergency and essential surgical healthcare services during COVID-19 in low- and middle-income countries: A perspective. *International Journal of Surgery*, 79, pp.43-46.

Machado Guimarães, C., Crespo de Carvalho, J. and Maia, A., 2013. Vendor managed inventory (VMI): evidences from lean deployment in healthcare. *Strategic Outsourcing: An International Journal*, 6(1), pp.8-24.

Maestre, J., Fernández, M. and Jurado, I., 2018. An application of economic model predictive control to inventory management in hospitals. *Control Engineering Practice,* 71, pp.120-128.

Mahapatra, S., Yu, D. and Mahmoodi, F., 2012. Impact of the pull and push-pull policies on the performance of a three-stage supply chain. *International Journal of Production Research,* 50(16), pp.4699-4717.

Manhas, A. K., Aubid, M., Rashid, H., Sheikh, M. A., & Syed, A. T., 2012,. Analysis of inventory of drug and pharmacy department of a tertiary care hospital. *Journal International Medical Sciences Academy,* 25(3), pp.183–185.

Marquès, G., Lamothe, J., Thierry, C. and Gourc, D., 2009. A supply chain performance analysis of a pull inspired supply strategy faced to demand uncertainties. *Journal of Intelligent Manufacturing,* 23(1), pp.91-108.

Masiye, F. and Chansa, C., 2019. Health Financing in Zambia.

Massimo Filippini & Giuliano Masiero & Karine Moschetti (2007): Characteristics of demand for antibiotics in primary care: an almost ideal demand system approach, *Quaderni della facoltà di Scienze economiche dell'Università di Lugano* 0701, USI Università della Svizzera italiana.

Maxwell, J., 2012. Qualitative research design. Thousand Oaks (Calif.): SAGE Publications, pp.216, 235, 237.

Mbhele, T., 2016. Decoupling paradigm of push-pull theory of oscillation in the FMCG industry. *South African Journal of Business Management,* 47(2), pp.53-66.

Medical Stores Limited., 2013., Implementation Plan for Regional Cross-docking Hubs., Lusaka

Medical Stores Limited., 2020a., Stock Status Report as at 31st March 2020., Internal Medical Stores Limited Report: unpublished

Medical Stores Limited., 2020b., Stock Status Report as at 29th April 2020., Internal Medical Stores Limited Report: unpublished

Medical Stores Limited., 2020c., Stock Status Report as at 29th June 2020., Internal Medical Stores Limited Report: unpublished

Medical Stores Limited., 2020d., Stock Status Report as at 15th July 2020., Internal Medical Stores Limited Report: unpublished

Medical Stores Limited., 2020e., Stock Status Report as at 30th August 2020., Internal Medical Stores Limited Report: unpublished

Medicines and Allied substances Act, 2013

Micah, A., Zlavog, B., Chen, C., Chapin, A. and Dieleman, J., 2018. Donor financing of human resources for health, 1990–2016: an examination of trends, sources of funds, and recipients. *Globalization and Health,* 14(1).

Ministry of Health, Zambia Household Health Expenditure and Utilisation Survey. 2015: Lusaka

Monk, E. and Wagner, B., 2013. Concepts in enterprise resource planning. [Mason, Ohio]: Course Technology / Cengage learning.

Montoya, R., Netzer, O. and Jedidi, K., 2010. Dynamic Allocation of Pharmaceutical Detailing and Sampling for Long-Term Profitability. *Marketing Science*, 29(5), pp.909-924.

Moons, K., Waeyenbergh, G. and Pintelon, L., 2019. Measuring the logistics performance of internal hospital supply chains – A literature study. *Omega*, 82, pp.205-217.

Mosey, A., 1991. Partition of Occupational Science and Occupational Therapy. *American Journal of Occupational Therapy*, 46(9), pp.851-853.

Mwisongo, A., Soumare, A. and Nabyonga-Orem, J., 2016. An analytical perspective of Global health initiatives in Tanzania and Zambia. *BMC Health Services Research*, 16(S4).

Nasheeda, A., Abdullah, H., Krauss, S. and Ahmed, N., 2019. Transforming Transcripts Into Stories: A Multimethod Approach to Narrative Analysis. *International Journal of Qualitative Methods*, 18, p.160940691985679.

Natarajan, K. and Swaminathan, J., 2014. Inventory Management in Humanitarian Operations: Impact of Amount, Schedule, and Uncertainty in Funding. *Manufacturing & Service Operations Management*, 16(4), pp.595-603.

Oomman, N., Bernstein, M., Rosenzweig, S., Okedi, W., Cheelo, C., Costa, D., and Mwamba, S., 2007. Following the Funding for HIV/AIDS. HIV/AIDS Monitor. Washington, DC

Ooms, G., Kibira, D., Reed, T., van den Ham, H., Mantel-Teeuwisse, A. and Buckland-Merrett, G., 2020. Access to sexual and reproductive health commodities in East and Southern Africa: a cross-country comparison of availability, affordability and stock-outs in Kenya, Tanzania, Uganda and Zambia. BMC Public Health, 20(1).

Parkhurst, J., Ghilardi, L., Webster, J., Snow, R. and Lynch, C., 2020. Competing interests, clashing ideas and institutionalizing influence: insights into the political economy of malaria control from seven African countries. *Health Policy and Planning*, 36(1), pp.35-44.

Pauwels, K., Simoens, S., Casteels, M. and Huys, I., 2015. Insights into European Drug Shortages: A Survey of Hospital Pharmacists. *PLOS ONE*, 10(3), p.e0119322.

Picazo, O F, F Zhao. 2009. Zambia health sector public expenditure review: accounting for resources to improve effective service coverage. World Bank Publications.

Piekkari, R. and Welch, C., 2012. Rethinking the Case Study in International Business and Management Research. Edward Elgar Publishing, p.173.

Quang, H., Sampaio, P., Carvalho, M., Fernandes, A., Binh An, D. and Vilhenac, E., 2016. An extensive structural model of supply chain quality management and firm performance. *International Journal of Quality & Reliability Management*, 33(4), pp.444-464.

Rabinovich, E. and Cheon, S., 2011. Expanding Horizons and Deepening Understanding via the Use of Secondary Data Sources. *Journal of Business Logistics*, 32(4), pp.303-316.

Rachmania, I. N., Basri, M. H., 2013. Pharmaceutical inventory management issues in hospital supply chains. *Management*, 3(1), 1-5

Rajaguru, R. & Matanda, M.J. 2013. 'Effects of interorganisational compatibility on supply chain capabilities: Exploring the mediating role of inter-organisational information systems (IOIS) integration', *Industrial Marketing Management*, 42: 620-632.

Randall, W. and Mello, J., 2012. Grounded theory: an inductive method for supply chain research. International *Journal of Physical Distribution & Logistics Management*, 42(8/9), pp.863-880.

ReAct. 2021. Access – Implement the plan – ReAct. [online] Available at: <https://www.reactgroup.org/toolbox/policy/implement-the-national-action-plan/access-to-antibiotics/> [Accessed 1 June 2021].

Ridder, H., 2017. The theory contribution of case study research designs. *Business Research*, 10(2), pp.281-305.

Ridley, D., 2012. The Literature Review. A Step by Step Guide for Students. England, London: SAGE Publications

Rizkya, I., Syahputri, K., Sari, R., Anizar, Siregar, I. and Ginting, E., 2018. Comparison of Periodic Review Policy and Continuous Review Policy for the Automotive Industry Inventory System. *IOP Conference Series: Materials Science and Engineering*

Rossetti M , Buyurgan N , Pohl E , Hall R . Medical supply logistics. Handbook of Healthcare System Scheduling 2012: pp. 245–80 .

Rossetti, M. D., Collins, T., & Kurgund, R., *2001*. Inventory cycle counting–a review. In The proceedings of the 2001 *Industrial Engineering Research Conference* (Vol. 1, pp. 457-463)

Rossin, D., 2012. Push-Pull Boundary Location, Information Quality, and Supply Chain Performance: An Exploratory Analysis. The Journal of Global Business Issues, 6(1).

Runeson, P. and Höst, M., 2008. Guidelines for conducting and reporting case study research in software engineering. *Empirical Software Engineering*, 14(2), pp.131-164.

Saha, E. and Ray, P., 2019. Modelling and analysis of inventory management systems in healthcare: A review and reflections. *Computers & Industrial Engineering*, 137, p.106051.

Sandelowski, M., 1995. Sample size in qualitative research. *Research in Nursing & Health*, 18(2), pp.179-183.

Sarley, David, Linda Allain, and Anup Akkihal., 2009. Estimating the Global In-Country Supply Chain Costs of Meeting the MDGs by 2015. Arlington, Va.: USAID | DELIVER PROJECT, Task Order 1

Schiele, H., 2018. Purchasing and Supply Management. Operations, *Logistics and Supply Chain Management*, pp.45-73.

Scroccaro, G., 2000. Formulary Management. *Pharmacotherapy*, 20(10 Part 2), pp.317S-321S.

Seidman, I. 2006. Interviewing as Qualitative Research 3rd ed. New York: *Teachers College Press*.

Seiter, Andreas. 2010. A Practical Approach to Pharmaceutical Policy. Directions in development ; human development. World Bank. © World Bank. https://openknowledge.worldbank.org/handle/10986/2468 License: CC BY 3.0 IGO

Shenton, A., 2004. Strategies for ensuring trustworthiness in qualitative research projects. *Education for Information*, 22(2), pp.63-75.

Silverman R, Keller J, Glassman A, Chalkidou K. Tackling the triple transition in global health procurement. Washington: Center for Global Development; 2019.

Singh, D. and Verma, A., 2018. Inventory Management in Supply Chain. Materials Today: Proceedings, 5(2), pp.3867-3872.

Smith, S. and Agrawal, N., 2000. Management of Multi-Item Retail Inventory Systems with Demand Substitution. *Operations Research*, 48(1), pp.50-64.

Sousa, R. and Voss, C., 2008. Contingency research in operations management practices. *Journal of Operations Management*, 26(6), pp.697-713.

Spearman, M.L. and Zazanis, M.A., 1992. Push and pull production systems: issues and comparisons. *Operations Research*, 40 (3), 512–532.

Stebbins, R., 2001. Exploratory research in the social sciences. Thousand Oaks [Calif.]: SAGE, pp.40-41.

Subramanian, L., Alexiou, C., Nellis J, J., Steele, P. and Tolani, F., 2020. Developing a sustainability index for public health supply chains. *Sustainable Futures*, 2, p.100019.

Sutters, C., 1990. THE MANAGEMENT OF A HOSPITAL FORMULARY. *Journal of Clinical Pharmacy and Therapeutics*, 15(1), pp.59-76.

Swaminathan, J. and Deshpande, V., 2021. Responsible Business Operations. Cham: *Springer International Publishing*, p.70.

Tabish, S A & K, Manhas & Aubid, Malik & Rashid, Haroon & A, Sheikh., 2012. Analysis of Inventory of Drug and Pharmacy Department of a Tertiary care Hospital. *Journal International Medical Sciences Academy.* 25. 183-185.

Tetnowski, J., 2015. Qualitative Case Study Research Design. *Perspectives on Fluency and Fluency Disorders*, 25(1), pp.39-45.

The Government of the Republic of Zambia, Ministry of Health, Health Sector Supply Chain Strategy and Implementation Plan 2015-2017, 2015

The Government of the Republic of Zambia, Ministry of Health. 2013. The 2012 List of Health Facilities in Zambia, Lusaka

The Government of the Republic of Zambia, Ministry of Health. 2018. National Health Accounts 2013–2016 Estimates. Lusaka

The Government of the Republic of Zambia, Ministry of Health., 2017. Health Financing Strategy: 2017-202, Lusaka

The Government of the Republic of Zambia, Ministry of Health., 2019. Health Sector Supply Chain Strategy and Implementation Plan 2019-2021

Todd D., 2011. The world medicines situation 2011 - Procurement of medicines. World Health Organization.

Toomey, John W., 2000., Inventory management: principles concepts and techniques, Springer Science +Business Media, LLC

Trading Economics, 2021. Zambian Kwacha | 2013-2021 Data | 2022-2023 Forecast | Quote | Chart | Historical. [online] Tradingeconomics.com. Available at: <https://tradingeconomics.com/zambia/currency> [Accessed 20 May 2021].

USAID., 2011. The Logistics Handbook: A Practical Guide for the Supply Chain Management of Health Commodities. Arlington, Va.: USAID | DELIVER PROJECT, Task Order 1.

Uthayakumar, R. and Priyan, S., 2013. Pharmaceutical supply chain and inventory management strategies: Optimization for a pharmaceutical company and a hospital. *Operations Research for Health Care*, 2(3), pp.52-64.

Van Weele, A., 2019. Purchasing & supply chain management. Andover: Cengage Learning EMEA. p. 3, 69, 269,

Vasileiou, K., Barnett, J., Thorpe, S. and Young, T., 2018. Characterising and justifying sample size sufficiency in interview-based studies: systematic analysis of qualitative health research over a 15-year period. *BMC Medical Research Methodology*, 18(1).

Vaz, F., Ferreira, A., Kulkarni, M., Motghare, D. and Pereira-Antao, I., 2008. A Study of Drug Expenditure at a Tertiary Care Hospital. *Journal of Health Management,* 10(1), pp.119-127.

Vila-Parrish, A. and Ivy, J., 2013. Managing Supply Critical to Patient Care: An Introduction to Hospital Inventory Management for Pharmaceuticals. *Handbook of Healthcare Operations Management,* pp.447-463.

Vila-Parrish, A. and Ivy, J., 2013. Managing Supply Critical to Patient Care: An Introduction to Hospital Inventory Management for Pharmaceuticals. *Handbook of Healthcare Operations Management*, pp.447-463.

Vila-Parrish, A., Ivy, J., King, R. and Abel, S., 2012. Patient-based pharmaceutical inventory management: a two-stage inventory and production model for perishable products with Markovian demand. *Health Systems*, 1(1), pp.69-83.

Vledder, Monique., Friedman, Jed., Yadav, Prashant., Sjöblom, Mirja., Brown, Tom . 2015. Optimal supply chain structure for distributing essential drugs in low income countries: Results from a randomized experiment. Tech. Rep. 1269, Ross School of Business, Ann Arbor, Michigan, USA

Waller, M., Cassady, C. and Ozment, J., 2006. Impact of cross-docking on inventory in a decentralized retail supply chain. Transportation Research Part E: *Logistics and Transportation Review*, 42(5), pp.359-382.

Wang, D., Liu, C., Zhang, X. and Liu, C., 2021. Does diagnostic uncertainty increase antibiotic prescribing in primary care?. *Primary Care Respiratory Medicine*, 31(1).

Wijffels, L., Giannikas, V., Woodall, P., McFarlane, D. and Lu, W., 2016. An enhanced cycle counting approach utilising historical inventory data. IFAC-PapersOnLine, 49(12), pp.1347-1352.

Wilding, R., 1998. The supply chain complexity triangle: Uncertainty generation in the supply chain. International *Journal of Physical Distribution & Logistics Management*, 28(8), pp.599-616.

World Bank Group., 2012. World Bank policy note : enhancing public supply chain management in Zambia, Washington, D.C.

World Health Organization Maximizing Positive Synergies Collaborative Group, 2009. An assessment of interactions between global health initiatives and country health systems. *The Lancet*, 373(9681), pp.2137-2169.

World Health Organization, 2017a. Access to medicines: making market forces serve the poor. [online] Available at: <https://www.who.int/publications/10-year-review/chapter-medicines.pdf?%20ua=1> [Accessed 22 April 2021].

World Health Organization, 2017b. Towards Access 2030: WHO Essential Medicines and Health Products Strategic Framework 2016-2030. Geneva. Available at: <https://www.who.int/medicines/publications/Towards_Access_2030_Final.pdf?ua=1> [Accessed 22 April 2021].

World Health Organization. 2021. Ndola, Zambia – London, England. [online] Available at: <https://www.who.int/patientsafety/implementation/apps/first_wave/ndola_london/en/> [Accessed 30 May 2021].

World Health Organization., 2000. The World health report 2000 : health systems : improving performance, Geneva

Yadav P, Tata H, Babaley M., 2011. The world medicines situation 2011 - Storage and supply chain management. World Health Organization.

Yadav, P. and Smith, L., 2014. Pharmaceutical Company Strategies and Distribution Systems in Emerging Markets. *Encyclopedia of Health Economics,* pp.1-8.

Yadav, P., 2015. Health Product Supply Chains in Developing Countries: Diagnosis of the Root Causes of Underperformance and an Agenda for Reform. *Health Systems & Reform,* 1(2), pp.142-154.

Yin, R., 2014. Case study research. 4th ed. London: Sage Publication, pp. 12-13, 40.

Zainal, Z., 2007. Case Study As a Research Method. *Jurnal Kemanusiaan*, 5(1).

Zambia Medicines and Medical Supplies Agency Act Act, 2019

Zhang, R., Wang, Q., Zhang, Y., Zheng, H. and Hu, J., 2019. Estimation of Jointly Normally Distributed Demand for Cross-Selling Items in Inventory Systems with Lost Sales. *Mathematical Problems in Engineering*, 2019, pp.1-21.

Zukhwa.ed.ac.uk. 2021. University Teaching Hospital, Lusaka | ZUKHWA. [online] Available at: <https://www.zukhwa.ed.ac.uk/members/members-list/university-teaching-hospital-lusaka> [Accessed 30 May 2021].

Appendix

Interview guides

Interview with ZAMMSA Informant

Name of Facilitator: _____
Name of Note taker: _____
Date: _____
Province: _____
District: _____
Entity Name: _____
Respondent's sex (Please circle one): Male Female
Respondent's job title: _____

Interview Start Time: End Time:

Introduction to study: We are two graduate students conducting research for our Master's Thesis for Lund University, Sweden, in collaboration with ReAct. We are investigating why stock outs of antibiotic drugs occur at hospitals in Zambia, and how these stock outs can be addressed through inventory management strategies. If you agree to partake in the study, this interview is expected to take about 45 minutes.

Objectives of the interview: The interview intends to provide an in-depth understanding of the healthcare system's supply chain leading to hospitals. In this interview, we hope to gain understanding of how inventory-related decisions are made, how information is shared across the supply chain and how inventory management strategies differ between different hospitals and for different medicines.

The results of the interview are intended to provide information relevant to assess the performance of the antibiotics supply chain leading to hospitals. The data collected in the interview will be transcripted and analysed in conjunction with other empirical data and supply chain literature, to describe how inventory management strategies at hospitals can address stock outs of antibiotics.

Confidentiality: With the interviewee's permission, the interview will be recorded. This is strictly for the purpose of making an accurate transcript, and the recording will be deleted as soon as the transcript is completed. The researchers will only attribute quotations to the interviewee with the explicit permission of the interviewee. The empirical data collected in the interview will be used strictly for the research clarified above, and not be dispersed to any other parties.

Interview Structure

Introductions	Presentation of interviewees, facilitators and interviewers
Interviewee's Perception of the Issue	Questions relating to: - Obstacles and bottlenecks to securing availability at the hospitals
Supply Chain Design and Logic	Questions relating to: - Role and mandate of actors in the supply chain - How orders are handled in the supply chain - Classification of medicines
Supply Chain Performance	Questions relating to: - Availability of antibiotics at central warehouse - Discrepancies between physical inventory and stock-level data - Order fulfillment - Differences between hospitals
Forecasting and quantification	Questions relating to: - The forecasting process - Forecasting accuracy - Information-sharing

Interview Guide

Welcome Mr/Mrs ___. Thank you for taking the time to participate in our interview.

{Introduce yourself and the facilitator, and briefly present the purpose of the interview.}

We'll begin with a brief introduction of who we are and our research: we are ___ and ___, two graduate students conducting research for our Master's Thesis for Lund University in Sweden, working in collaboration with ReAct, who has kindly facilitated this interview. We are investigating why stock outs of antibiotic drugs occur at hospitals in Zambia, and how these stock outs can be addressed through inventory management strategies.

With your permission, the interview will be recorded. This is strictly for the purpose of making an accurate transcript. Is this alright with you?

We can take the opportunity to mention that we are running on a tight schedule and might need to moderate the length of the answers in order to cover all questions. We therefore excuse any interruptions in advance.

Other than that we can move on to the interview, we would be grateful if you could give a brief introduction of who you are and your role at ZAMMSA.

If it sounds okay with you, we would like to begin with talking about your perception of the issue at hand.

What do you consider to be the most important obstacles and bottlenecks to secure the availability of medicines in general and antibiotics in particular at tertiary hospitals in Zambia?

Moving on, we would like to talk about the general design and logic of the supply chain.

At what decision level are inventory management strategies decided?
{Probe for to what extent can hospitals decide their own inventory management policies (e.g. safety stock levels, reorder points, etc)}

Besides the replenishment orders delivered according to the ZAMMSA's distribution schedule, what other types of orders are there?
{Probe for if all other orders outside of the distributions schedule are categorised as emergency orders}

In what way are medicines classified in the healthcare system's supply chain and how does this affect how they are handled?
{Probe for if…

- *antibiotics are handled differently than other medicines*
- *demand fluctuation is taken into account*

- *safety stock levels and reorder points are affected by these classifications}*

We would like to talk more about the performance of the supply chain.

Are there any issues with orders from the central warehouse not being delivered to tertiary hospitals on schedule?
{If yes: ask about if long lead times is an issue}

Are there any issues with orders from the central warehouse not being delivered to tertiary hospitals in full quantity?
{If yes: probe for if stock outs occuring at the central warehouse is an issue}

Does the availability vary systematically between drugs on the essential medicines list?
{Probe for examples and explanations as to what causes the variations}

Does the availability vary systematically between tertiary hospitals?
{Probe for explanation as to what causes the variations}

We would like to talk more about how forecasting is being performed.

How is forecasting and quantification of demand performed?
{Probe for how consumption data is monitored, reported and analysed}

Who performs the forecasting?
{Probe for to what extent hospitals are performing forecasting themselves}

What are the main difficulties in forecasting?
{Probe for examples}

How is data used for forecasting shared between tertiary hospitals and ZAMMSA?
{Probe for known issues with information-sharing}

How well does forecasting data generally correspond to the actual demand, and is it up to date?
{Probe for where the problem stems}

Would you like to have more input or contributions to forecasting?

If you could make any changes to improve the forecasting process, what would they be?

Thank you for all the insightful information. Is there anything else you think affects the availability of antibiotics at hospitals that has not been brought up?

{You have now reached the end of the questionnaire}

Interview with Tertiary Hospital Pharmacy Informant

Name of Facilitator: _____
Name of Note taker: _____
Date: _____
Province: _____
District: _____
Facility Name: _____
Respondent's sex (Please circle one): Male Female
Respondent's job title: _____

Interview Start Time: End Time:

Introduction to study: We are two graduate students conducting research for our Master's Thesis for Lund University, Sweden, in collaboration with ReAct. We are investigating why stock outs of antibiotic drugs occur at hospitals in Zambia, and how these stock outs can be addressed through inventory management strategies. If you agree to partake in the study, this interview is expected to take about 45 minutes.

Objectives of the interview: The interview intends to provide an in-depth understanding of how inventory management strategies are being used at hospitals to ensure availability of antibiotics. The interview will also extract information about perceived obstacles and bottlenecks to ensuring availability, and how the hospital orders and receives antibiotics. We are interviewing informants at selected hospitals in Zambia, and this hospital was selected as one of the case objects.

The data collected in the interview will be transcripted and analysed in conjunction with other empirical data and supply chain literature, to describe how inventory management strategies at hospitals can address stock outs of antibiotics.

Confidentiality: With the interviewee's permission, the interview will be recorded. This is strictly for the purpose of making an accurate transcript, and the recording will be deleted as soon as the transcript is completed. The researchers will only attribute quotations to the interviewee with the explicit permission of the interviewee. The empirical data collected in the interview will be used strictly for the research clarified above, and not be dispersed to any other parties.

Interview Structure

Introductions	Presentation of interviewees, facilitators and interviewers
Interviewee's Perception of the Issue	Questions relating to: - Obstacles and bottlenecks to securing availability at the hospital
Demand and Supply Characteristics	Questions relating to: - Demand fluctuation - Supply reliability and responsiveness
Inventory Management Strategies at the Hospital	Questions relating to: - Role and mandate of actors in the supply chain - How orders are handled in the supply chain - Classification of medicines
Inventory Management Performance	Questions relating to: - Availability of antibiotics at the Hospital - Discrepancies between physical inventory and stock-level data - Reliance on emergency orders
Forecasting and quantification	Questions relating to: - The forecasting process - Forecasting accuracy - Information-sharing

Interview Guide

Welcome Mr/Mrs ___. Thank you for taking the time to participate in our interview.

{Introduce yourself and the facilitator, and briefly present the purpose of the interview.}

We'll begin with a brief introduction of who we are and our research: we are ___ and ___, two graduate students conducting research for our Master's Thesis for Lund University in Sweden, working in collaboration with ReAct, who has kindly facilitated this interview. We are investigating why stock outs of antibiotic drugs occur at hospitals in Zambia, and how these stock outs can be addressed through inventory management strategies.

With your permission, the interview will be recorded. This is strictly for the purpose of making an accurate transcript. Is this alright with you?

We can take the opportunity to mention that we are running on a tight schedule and might need to moderate the length of the answers in order to cover all questions. We therefore excuse any interruptions in advance.

Other than that we can move on to a brief introduction of who you are and your role at the hospital.

If it sounds okay with you, we would like to begin with talking about your perception of the issue at hand.

What do you consider to be the most important obstacles and bottlenecks to secure the availability of antibiotics at hospitals in Zambia?

Moving on, we would like to talk about the demand and supply characteristics of antibiotics.

Does the hospital where you work have a hospital formulary? If so, does this formulary accurately meet demand and the needs of the population you serve?

How much does the demand for antibiotics fluctuate?
{Probe for to what extent demand fluctuation differs compared to other medicines, and if there is a lot of variation between different antibiotics}

Are medicines with highly fluctuating demand a challenge in inventory management at the hospital?

Are there any issues with orders from the central warehouse not being delivered to hospitals on schedule?
{If yes: probe whether long lead times are an issue, and if there are differences between emergency and regular orders}

Are there any issues with orders from the central warehouse not being delivered to hospitals in full quantity?

{If yes: probe for if stock outs occuring at the central warehouse is an issues, and if there are differences between emergency and regular orders}

We would like to talk more about the hospital's inventory management strategies.

At what level are inventory management strategies decided?
{Probe for to what extent hospitals can decide their own inventory settings for hospital inventory (e.g. safety stock levels, reorder points, etc)}

In what way are medicines classified in the hospital's inventory management system and how does this affect how they are handled?
{Probe for if…

- *antibiotics are handled differently than other medicines*
- *demand fluctuation taken into account*
- *safety stock levels and reorder points are affected by these classifications*

Also: Do you believe that the current classifications sufficiently account for the varying demand characteristics of medicines?}

Are there occurrences when the hospital cannot fully follow standard operating procedures?
{Probe for if this is non-deliberate (e.g. capacity-related) or deliberate (e.g. inefficient standard operating procedures)}

We would like to talk more about the hospital's inventory management performance.

How big of an issue is stock outs of antibiotics at the investigated hospital?

Does the extent of the issue vary systematically between different drugs on the essential medicines list?
{Probe for examples and explanations as to what causes the variations}

Are there occurences of the hospital having to use emergency orders systematically?
{Probe for information about how often emergency orders are placed, and if common, probe for why they are common}

We would like to talk more about how forecasting is being performed.

How is forecasting and quantification of demand performed?
{Probe for how consumption data is monitored, reported and analysed}

Who performs the forecasting?
{Probe for to what extent hospitals are performing forecasting themselves}

What are the main difficulties in forecasting?
{Probe for examples}

How is data used for forecasting shared between tertiary hospitals and ZAMMSA?
{Probe for known issues with information-sharing}

How well does forecasting data generally correspond to the actual demand, and is it up to date?
{Probe for where the problem stems}

Thank you for all the insightful information. Is there anything else you think affects the availability of antibiotics at hospitals that has not been brought up?

{You have now reached the end of the questionnaire}