MODELING STOCK LEVELS OF MALARIA RAPID DIAGNOSTIC TEST KITS AND NEVIRAPINE SYRUP IN OSHANA REGION, NAMIBIA

A RESEARCH SUBMITTED IN FULFILMENT OF THE REQUIREMENT FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN PUBLIC HEALTH

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ABSTRACT

Malaria and HIV/AIDS are two most widely spread diseases in Sub-Saharan Africa. The co-infection is very common in the region, especially in unstable malaria transmission areas with the prevalence of 29.9 - 40%. In Namibia these two diseases are common in northern eastern regions, which are unstable malaria transmission areas. These two diseases affect poorer segments of the population. Individually and biologically Malaria increases viral load of HIV people. The severity of malaria is more in pregnant women and children as well as people live with HIV. Equity access of malaria diagnostic test kits and NVP syrup is critical in control these two epidemic diseases. Given the nature of current conditions, justification exists for a study to develop and demonstrate a mathematical modeling of estimating stock levels, which can establish parameters to prevent stock-outs of mRDT and NVP syrup.

The study adopted a mixed-method design in order to provide a broader perspective of modeling of stock levels in public health facilities, which underpins the delivery of mRDT for testing malaria and NVP syrup for PMTCT. In its quantitative aspect, the study adopted a descriptive approach to acquire data from a period of five years retrospectively, in this case 2012 to 2016 inclusive. Data were mainly obtained from Syspro, DHIS and EDT softwares. The data were analysed using SPSS version 23 software, in which time series analysis was applied to determine forecasted consumption of mRDT and NVP syrup. The correlation coefficient and Binary logistic regression were used to identify factors associated with stock-out of mRDT and NVP syrup. Mathematical models of stock levels were developed and validated.

The findings showed that due to seasonal variation and other unforeseen variables, the consumption of mRDT and NVP syrup in public health facilities is increasing every quarter, while delivery lead time being a main factor and predictor of stock out. The model developed found to have predictive accuracy of more than 70% in estimating stock levels. The use of this supply models will curb unnecessary costs due to irregular orders. Furthermore, the model will contribute to the prevention of stock out and diseases control. It is a recommendation that similar models should be developed for other medicines such as anti TB, other ARVs and antihypertensive drugs.

LIST OF PUBLICATIONS

1. **Magesa,E.,**Angula,P.,Kabwebwe,M. “Factors Associated with Stock Out of Malaria Diagnostic Test Kit.” *Journal of public health in Africa* (Accepted on 16th August, 2019)
2. **Magesa,E.,**Kabwebwe,M.,Angula,P. “Time Series Analysis of Nevirapine Syrup Consumption in Prevention of Mother to Child Transmission and its Optimal Supply Chain Model in Oshana Region, Namibia.” *Journal of public health in Africa* (Accepted on 20th August, 2019)

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ACT	Artemisinin Combination Therapy
AIDS	Acquired Immune Deficiency Syndrome
AL	Artemether Lumefantrine
AMC	Average Monthly Consumption
ANC	Ante Natal Care
ART	Antiretroviral Therapy
ARV	Antiretroviral
AU	African Union
CBART	Community-Based Anti-Retroviral Therapy
CD_4	Cluster of Differentiation 4
CDC	Centre for Disease Control and Prevention
CHW	Community Health Worker
CMA	Centered Moving Average
CMS	Central Medical Store
CSL	Customer Service Level
DHS	Demographic Health Survey
DNA PCR	Deoxyribonucleic Acid Polymerase Chain Reaction
DSP	Directorate of Special Program
EDT	Electronic Dispensing Tools
EML	Essential Medicine List
FEFO	First Expire First Out
FESC	Facility Electronic Stock Cards
FIFO	First In First Out
GFATM	Global Fund for AIDS, Tuberculosis and Malaria
GHSC	Global Health Supply Chain
GHSC-PSM	Global Health Supply-Chain Procurement and Supply-Chain Management
HCs	Health Centres
HIV	Human Immunodeficiency Virus
IHO	Intermediate Hospital Oshakati
IEC	Information Education and Communication

IOM	Institute of Medicine
LMICs	Low and Middle Income Countries
LT	Lead Time
LWS	Local Wholesaler Supplier
MA	Moving Average
MOHSS	Ministry of Health and Social Services
mRDT	Malaria Rapid Diagnostic Test
MSH	Management Science for Health
MTCT	Mother-To-Child Transmission.
NAPPA	Namibia Planned Parenthood Association
NEMLIST	Namibia Essential Medicine List
NHSC	Namibia Health Supply Chain
NIP	Namibia Institute of Pathology
NMPC	National Medicine Policy Co-ordination
NVDCP	Namibia Vector Diseases Control Program
NVOCC	Non-Vessel Operating Common Carrier
NVP	Nevirapine
NSP	National Strategic Plan
OOS	Out Of Stock
OMRMD	Oshakati Multi-regional Medical Depot
PEPFAR	President's Emergency Plan for AIDS Relief
PHC	Primary Health Care
PMTCT	Preventive Mother to Child Transmission
PMO	Principal Medical Officer
PLWH	People Living with HIV
PSOP	Pharmaceutical Standard Operating Procedures
RDTs	Rapid Diagnostic Test Kits
RMD	Regional Medical Depot
SADC	Southern Africa Development Community
SCMS	Supply Chain Management System
SPS	Strengthen Pharmaceutical System

SSA	Sub-Saharan Africa
STG	Standard Treatment Guidelines
TAP	Treatment Acceleration Plan
UNAIDS	United Nations Programme on HIV and AIDS
UNAM	University of Namibia
VCT	Voluntary Counseling and Testing
WHO	World Health Organization

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DEDICATION

I dedicate this dissertation to my family and many friends. A special feeling of gratitude I wish to express to my loving wife, Agatha Thomas Mkonyi, whose encouragement and push for tenacity still rings in my ears. My children, Daniel, Abagail, Gideon and Matilda have never left my side and are very special. I also dedicate this work to my many friends and pastor, Gerhard Gorbes, who have supported me throughout the process. I dedicate this work and give special thanks to my father, Salvatory Boniface Magesa, and my mother, Matilda Alphonce Kayoza, for being there for me throughout the entire doctoral programme. You have been my best cheerleaders.

DECLARATIONS

I, Emmanuel Magesa, hereby declare that this study is my own work and is a true reflection of my research, and that this work, or any part thereof has not been submitted for a degree at any other institution.

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Name of Student **Signature** **Date**

CHAPTER 1: INTRODUCTION

1.1 Orientation/Background

Stock out of medicines is a public health concern in many public health facilities in developing countries, including Sub Saharan Africa (SSA) (1). Recently there has been much interest worldwide in the concept of modeling of stock levels of essential medicines and diagnostic test kits in supply chain system (1). It is the main component of a systematic programme for the treatment of disease (1). Controlling of stock levels of essential medicines and diagnostic test kits involve complex networks of heterogeneous stakeholders in both the public and private sectors, which include resources, technology, activities and information (1-3).

In SSA, concept of modeling stock levels of essential medicines and diagnostic test kits has not been embraced much, however, over the previous decade, SSA states have received massive funding from international donors to strengthen their supply chains from the higher level to the lower level. The mainly focus is on medication and diagnostic test kit to treat communicable diseases such as malaria and Human Immunodeficiency Virus (HIV). Malaria and HIV are two of the most important diseases facing Africa, SSA in particular. The association of these two infections has important public health implications. They have been labeled by the African Union (AU) as “emerging diseases” on the African continent due to the fact that they place a heavy economic burden on African countries, especially in SSA (4-9). It is estimated that 38 million Africans are infected with HIV, whereas about 300 million suffer from malaria each year (5-6). It has been reported that, HIV infection had an expected large association

with the outcome of falciparum malaria, especially in the region of unstable transmission compared to non HIV patients. This contributes to HIV/ Malaria prevalence of about 30%. The severity in terms of morbidity and mortality is more in mothers and their newborn (9).

As a strategy to reduce the burden of these diseases to adults and children, many sub-Saharan countries established supply chains of Malaria Rapid Diagnostic Test Kits (mRDT) for malaria screening for every patient who is presenting with fever at the public health facilities and the use of nevirapine (NVP) syrup to children born with HIV positive mothers (10).

Effective management of malaria and HIV/AIDS requires uninterrupted availability of both mRDT and NVP syrup within the distribution system (11). However, recent studies have indicated stock-outs of these two pharmaceutical items are not reported in a timely manner due to ineffective stock management (12, 13). The ineffective stock management of mRDT and NVP syrup impacts patient survival and growth in case of children, by increasing the probability of complications due to the lack of appropriate therapy, insufficient viral suppression, drug-resistance mutation and eventually increases mortality and morbidity (14-19).These problems compromise the quality of health care and inadequate supply may contribute to increased workloads for already stressed healthcare staff, due to the fact that patients who do not have adequate medication may require more personal care (20). The nature, usage and specific characteristics of malaria diagnostic test kits and antiretroviral medicines pose challenges for supply-chain management (6). For those reasons, product delivery, connecting producer and manufacturers to patients may require critical rethinking. The world is moving towards implementation of the so-

called 90-90-90 strategy, meaning that 90% of people living with HIV (PLWH) should know their status, 90% of diagnosed PLWH should be on treatment and 90% of PLWH on treatment should achieve an undetectable viral load, by the year 2020. Another goal of the industry internationally is an achievement of universal testing for malaria before treatment. (17).

Namibia, a country in SSA is also experiencing the burden of HIV/AIDS and malaria. HIV is at an estimated adult prevalence of 17.2%, which is the fifth highest in the region (15). More than 250,000 PLWH are receiving ARVs medicines (11, 20). In the case of malaria, there has been a sharp improvement in the situation following support from stakeholders and the introduction of mRDT to health facilities in the country. However, outbreaks of malaria between 2014 and 2017, due to floods in the northern regions (Kavango East, Kavango West, Ohangwena, Omusati, Oshana and Zambezi) are hampering progress in the control and elimination of malaria. It is estimated that in 2017, more than 11,000 people contracted malaria in Namibia. About 18 people died from the disease. This statistic is almost three times the number of cases recorded in 2015 and 2016 (21). In order to ease the impact of HIV/AIDS and embark on a campaign to eliminate malaria, effective systems and strategies are crucial to ensure the uninterrupted supply of ARV and RDT (8, 12, 15, 21, and 22).

1.2 Statement of the Problem

Together, malaria and HIV/AIDS cause more than four million deaths each year globally (23). In Namibia, these two communicable infections remain a major public health problem, particularly in the northern and eastern parts of the country (24,25). However, significant reduction in malaria and HIV morbidity and mortality were observed on an annual basis until 2012. According to the Ministry of Health and Social Services' strategic plan of 2017/2018 to 2021/2022, Namibia has observed an upsurge in HIV and malaria cases and deaths in 2014 till 2017 (26,27).

Availability of Antiretroviral drugs and malaria test kit are the key factors in limiting the epidemic of these communicable diseases, in which HIV relies on a constant supply uninterrupted for the duration of a patient's life, while disease such as malaria that is approaching elimination in Namibia, but that is highly reliant on the adequacy of diagnostics and supply of the rapid tests therein (28).

Namibia operates an integrated pharmaceutical supply chain model whereby the central medical store (CMS), a government entity, oversees the procurement, storage and distribution of all pharmaceuticals and clinical supplies for use in public health facilities in Namibia. With this logistic and supply system, the overall stock out rate of medicines is 25% (28, 29, 30, 31 and 32). Country like Nigeria with the similar pharmaceutical supply chain logistics has the overall stock rate of >30 %.(29)

The situation of stock out may be caused by shortage of pharmacy staffs and the absence of a clear picture of aggregation of consumption figures of medicines in medical stores and within health facilities, fragmented supply chain, long lead time and potentially

duplicating efforts across the supply chain. All these can lead to under-supplying or over-supplying, eventually creating stock-out of medicines and diagnostic test kits.

In Namibia, the study of modeling stock levels, which outcomes known of significantly reducing stock out rates have just not been well studied. Due to the deficiency, this study has examined the stock levels in Oshana region and developed a potential model which estimate the stock levels of mRDT and NVP syrup.

1.3 Objectives

1.3.1 Main objective

- To investigate a potential model of estimating stock levels of mRDT and Nevirapine syrup in public health facilities in Oshana region, Namibia

1.3.2 Specific Objectives

- To examine the consumption rates of mRDT and NVP syrup in Public health facilities in Oshana region.
- To identify factors associated with stock-out of mRDT and NVP syrup in Public health facilities.
- To develop a potential mathematical model for mRDT and NVP syrup in the health care system.
- To validate mathematical stock level model using Monte Carlo simulation technique.

The study has three primary components: a situational analysis (to address the first two objectives), an optimal mathematical modeling of stock levels of mRDT and NVP syrup (to address the third objective), and Validation of the potential model of stock levels by way of a simulation (which addresses the fourth objective).

1.5 Limitations

Due to the fact that the research was done in Oshana region, Namibia. The researcher excluded

- Procurement of mRDT and NVP syrup
- Regulatory requirements and processes for medicines
- Pharmaceutical manufacturing

1.6 Definition of Terms

Antiretroviral (ARV). Medication for the treatment of infection caused by HIV retroviruses, In this study, Antiretroviral medicine refers to the NVP syrup (34, 49).

Artemisinin-based combination therapy (ACT). A combination of Artemisinin, or one of its derivatives, with antimalarial or antimalarials of a different class. Currently artemisinin-based combination therapy (ACT) is recommended for the treatment of P. Falciparum malaria. ACT also refers commonly to Artemether-Lumefantrine (AL) (15).

Average consumption (CA). Average stock consumed over an order interval. The CA of NVP syrup or RDTs may vary. It is recommended that the statistic be monitored and

recalculated every three to four months. Changes in CA will affect recommended minimum and maximum levels and should be adjusted accordingly (65).

Closing stock. The quantity of a specific medicine available at the end of a month **(**65).

Continuous inventory review (also known as perpetual review). A system that tracks each item and update inventory counts each time an item is removed from the inventory (72).

Delivery lead time. The time elapsed between the receipt of a health facility's order to the delivery of the NVP syrup or mRDT (65).

Delivery note. A document accompanying a shipment of medicines or diagnostic test kits (NVP syrup or mRDT) that indicates the description and quantity of NVP syrup or mRDT delivered (65).

Developing country. Referred to low and middle income countries (43, 56).

Essential medicine. A medicine that satisfies the healthcare needs of the majority of a population. Essential medicines should be available at all times, in adequate amounts and appropriate dosage forms, and at a price the community can afford. This study defines NVP syrup as the essential medicine under review (64, 66).

Healthcare system. Facilities, organisations and trained personnel engaged in providing health care within a specified geographical area (34).

HIV/AIDS. Acquired immunodeficiency syndrome (AIDS) is a chronic, potentially life-threatening condition caused by the human immunodeficiency virus (HIV). By damaging

the immune system, HIV interferes with the body's ability to fight organisms that cause disease. It is commonly transmitted sexually (45).

Holding cost. Costs associated with holding inventory that remains unsold. These costs are one component of "total inventory costs", which include ordering costs and shortage costs (70).

Initial stock. The quantity of NVP syrup and mRDT available at the beginning of a month (65).

Inventory (stock) control. Operations, logistics and supply-chain management, the technological system and software necessary to manage inventory (65).

Inventory system. A system which controls the level of inventory by establishing the amount of stock which should be ordered (the level of replenishment) and when it should be ordered (19).

Invoice. An itemised billing for medicine sold or services provided, which indicates the price of individual items that are billed, the total amount billed and the terms (65).

Informant. For the purpose of this study, any person who plays a key role in the supply chain of ARV medicine and mRDT in Oshana region (45).

Malaria. An infectious disease characterized by cycles of chills, fever and sweating, caused by the parasitic infection of red blood cells by a protozoan of the genus Plasmodium, which is transmitted by the bite of an infected female mosquito **(**26).

Malaria rapid diagnostic test (mRDT). An antigen-based stick, cassette or card test for malaria in which a colored line indicates that plasmodial antigens have been detected (56).

Maximum stock level (Qmax). The quantity of ARV, malaria medicines and diagnostic tests on hand at a facility, needed to satisfy demand until the next order is received. This can be calculated by adding the product of the procurement period and average consumption to the minimum stock level **(**65).

Model. A representation of a system using general rules and concepts.

Central medical store (CMS). A facility responsible for developing, maintaining and managing an efficient and cost-effective system of procurement, storage and distribution of approved, essential medicines and medical supplies required for use by public-health services as designated by the Ministry of Health and Social Services.

Regional medical store/depot. A facility that receives essential medicines and supplies from the central medical store and holds and distributes them to four, northern regions including Oshana region. In this study, the regional medical store is the Oshakati Multi-regional Medical Store (65).

Minimum stock level (Qmin) also known as reorder point). The quantity of ARV, malaria medicines and diagnostic tests that should always be on hand to prevent stock-outs. This can be calculated by obtaining the product of the lead time (LT) and the average consumption (CA) plus predetermined or recommended safety stock (SS). The recommended minimum stock level for facilities in Namibia is the average consumption

during a period which is twice the order interval and should be indicated on the stock card (65).

Ordering costs. Expenses incurred to create and process an order, to a supplier (42).

Delivery lead time (LT). The period of time between placement of an order by the regional medical store or health facility of ARV or mRDT, and receipt of same from the central medical store or regional medical store (65).

Periodic inventory review. Counting and documenting inventory at specified times**.** (71)

Pharmaceutical standard operating procedures. Guidelines that specify, in writing, how a pharmacy staff and its supervisor should accomplish a task (65).

Pharmaceutical supply chain. The management of product supply, from sourcing raw materials to manufacturing active ingredients through formulation, packaging and distribution to the patient. It involves a system of organisations, people, activities, information and resources that move a product or service from supplier to customer (61, 77).

Primary Health Care. The entry point of Caregiving, based on scientifically sound and socially acceptable methods and technology, which makes universal health care accessible to individuals and families in a community (22).

Procurement Period. The time period between two orders (61,77).

Rapid diagnostic test (RDT). A medical diagnostic test that is quick and easy to perform. RDT is suitable for preliminary or emergency medical screening and for use in medical facilities with limited resources. In this study, RDT refers to mRDT **(**42).

Safety stock/buffer stock level. The quantity of essential medicine or mRDT available to prevent a stock-out (22, 65).

Stock consumption. The quantity of essential medicines or mRDT consumed by patients over a specified period of time (22).

Stock card (or bin card). The document that records the status of essential medicine (NVP syrup) or mRDT held in a stockroom **(**65).

Stock levels. Stock level refers to the different levels of stock which are required for an efficient and effective control of mRDT and NVP syrup and to avoid over and under-stocking of materials.

Stock-out. The quantity of NVP syrup (essential medicine) or mRDT needed by health facilities at a storage or delivery point, which is not available at the time of demand (66).

Stock-out cost. The effective cost in loss of sales, profits and goodwill associated with the inability to draw on stocks of raw material, finished goods, or work-in-progress (66, 80). “Production dislocation” may also be considered a cost.

Supplier. In this study, the provider of raw materials to a manufacturer (77).

Supply chain management (SCM). The oversight of materials (medicines), information and financial resources as they move in process from a supplier to a manufacturer to a wholesaler to a retailer to a consumer (37,77).

Uncomplicated malaria. Symptomatic infection with malaria parasitemia without signs of severity and/or evidence of vital organ dysfunction (78, 80).

1.7 Significance of the Study

This study provided essential information and tools that will support decision-making processes and help formulate health policy and promote public health, patient safety, and strategic decision-making in the pharmaceutical supply chain in Namibia. Furthermore, the study will contribute to global and regional knowledge banks of pharmaceutical supply-chain efficiency. Execution of the optimal model may help minimise the size of inventories of mRDT and NVP syrup held by storage facilities, yet be sufficient for the adequate medical treatment, patients who seek health care from public health facilities in Oshana region and Namibia at large. Future students and researchers who carry on research on the same or related issues, may find the study useful for broadening their understanding and knowledge of stock level models.

1.8 Summary

Chapter one laid a foundation for the current study. It introduced the research problem and objectives. The purpose of the research was described, the methodology was briefly explained and justified, terms were defined, justification for the study was presented, the study was outlined and its limitations were noted. The study proceeded with a detailed description of the research which is organised in five further chapters as follows: Chapter two will place the study within the context of relevant literature. Chapter three addresses

research methodology and methods employed in the study. Chapter four presents findings regarding consumption trends of NVP syrup and mRDT, their forecasting, calculation of delivery times (based on past records), safety stock and procurement periods, in conjunction with factors associated with stock-outs of NVP syrup and mRDT. Chapter five presents a detailed discussion of the findings presented in chapter four and develops the supply-chain model proposal based on the analysis and the discussion.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Several studies (5,33,34,35, 36) including stock or inventory management database ,like EDT (Electronic dispensing tool) and SYSPRO have been used and conducted to determine how supply chains of medicine can be improved to prevent the stock-out of medicines. The literature presents the concept of supply chains in a different context.

The literature review focuses on the association of malaria and HIV, inventory management, storage, transportation and distribution, consumption or demand. The supply-chain model can be a useful tool for minimizing or preventing the occurrence of stock-outs of medicine and diagnostic test kits at various levels in the supply chain. This study focuses its attention on developing an optimal supply-chain model, specifically for essential diagnostic test kits for malaria and for NVP syrup, a medicine used in the treatment of HIV/AIDS for babies born to HIV positive mothers.

In this chapter different search engines such as PubMed was used in this study to select scientific papers, journals and books with the similar or related research topics. The key search terms were association of HIV and malaria, antiretrovirals (ARVs) and malaria diagnostic test kit stock out, medicines supply chain models, inventory supply models, quantifications and probability distribution models. Using those search engines literatures selected were mostly from Africa and not more than five years old.

2.2 Conceptual Framework of Factors associated with Stock out of mRDT and NVP syrup.

In this research, the conceptual model constructs a framework how major different factors within the supply-chain system can cause a shortage or stock-out of NVP syrup and mRDT, and how these occurrences can be examined and described. The conceptual framework also helps determine the causes for inaccurate orders placed by health facilities and throws light on the challenges involved collecting consumption data. An effective supply chain on its own will not provide NVP syrup or mRDT security. An efficient supply chain also requires effective service delivery and other programmatic interventions, such as information, education and communication (IEC) and the existence of supportive legal and social-environmental policies (37). Established on the literature review, the cognition of the employees, policy, storage capacity, weak monitoring and supervision, transport and communication are studied as causal agents for the occurrence of stock-outs of essential medicines like NVP syrup and diagnostic test kits like mRDT.

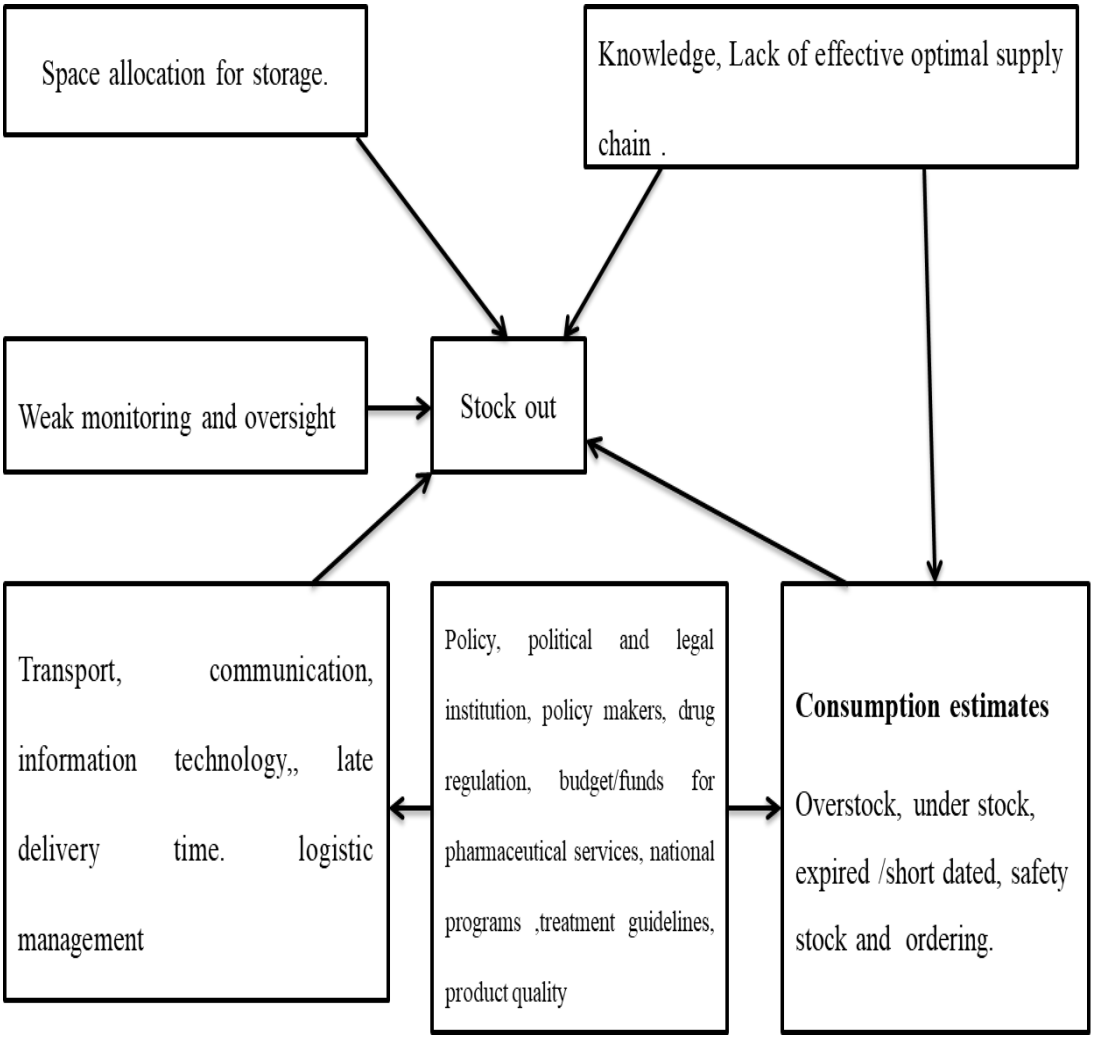


Figure 1. Illustrates the conceptual framework of variables that causes stock out of mRDT and NVP syrup in Oshana. Adapted and modified from the conceptual framework of Organizational practices influencing availability of essential medicines in hospitals (38).

Several studies (5, 10, 35-40) have been carried out to establish the factors associated with stock-outs of essential medicines in public health facilities.

2.2.1 Factors associated with the availability and utilization of mRDT

Malaria rapid diagnostic test kit (mRDT) is one of the pillars of malaria control. It is relatively simple to perform and provide quick results for treatment decisions. However, its use and availability depends on several factors such as skilled workers, transport, ordering e.t.c. The following are studies done in different areas to determine the factors associated with utilization and availability of mRDT.

A cross-sectional study was conducted in Zamfara State, Nigeria to assess factors influencing utilization of mRDT in different health facilities. About 306 health care workers were selected using multistage sampling from six Local Government Areas. A pre-tested self-administered questionnaire was used to collect information on the knowledge, use of mRDT and factors influencing utilization. An observational checklist was used to assess the availability of mRDT in the six months prior to this study. The findings show that overall, 198 (64.7%) of health workers had good knowledge of mRDT; mRDT was available in 33 (61.1%) facilities. Routine use of mRDT was reported by 253 (82.7%) health care workers. This comprised 89 (35.2%) laboratory scientists/technicians, 89 (35.2%) community health extension workers/community health officers; 59 (23.3%) nurses and 16 (6.3%) doctors. Health workers' good knowledge of mRDT, trust in mRDT results, having received prior training on mRDT, and non-payment for mRDT were predictors of mRDT utilisation. This study demonstrated that healthcare worker utilisation of mRDT was associated with health worker and health system-related factors that are potentially modifiable. With that recommendation, there is a need to sustain training of healthcare workers on the benefits of using mRDT and the provision of free mRDT in health facilities (41).

Another cross sectional survey to explore factors that affect the performance and use of mRDTs was conducted in the primary care facilities in South Africa. Twenty nurses were randomly selected from 17 primary health care facilities, three nurses from hospitals serving the study area and 10 other key informants, representing the managers of the malaria control programs, routine and research laboratories, were interviewed, using semi-structured questionnaires. The findings show that, there was a high degree of efficiency in ordering and distribution of mRDT, however, only 13/20 (65%) of the health facilities had appropriate air-conditioning and monitoring of room temperatures. Sixty percent (12/20) of the nurses did not receive any external training on conducting and interpreting mRDT. Fifty percent of nurses (10/20) reported mRDT stock-outs. Only 3/20 nurses mentioned that they periodically checked the quality of mRDT. Fifteen percent of nurses reported giving antimalarial drugs, even if the mRDT was negative. The study concluded that, storage, quality assurance, end user training and use of mRDT results for clinical decision making in primary care facilities in South Africa need to be improved (42,43).

A study on factors associated with stock out of mRDT was conducted in Mozambique in which health facilities in Maputo (low malaria burden), Inhambane (moderate), and Nampula (high) Provinces were selected using probability proportionate to the number of Community health workers (CHWs) at each facility. All CHWs and their supervisors at selected facilities were interviewed using a structured questionnaire to document experiences with kit commodities. Data were analysed to assess CHW commodity stock levels by province and season. The results indicate that, in total, 216 CHWs and 56 supervisors were interviewed at 56 health facilities. CHWs reported receiving an average

of 6.7 kits in the last year, although they are intended to receive kits monthly. One-tenth of CHWs reported receiving kits with missing mRDT. Commodity use was highest in the rainy season. Stock outs were reported by CHWs in all provinces, more commonly in the rainy season. Facility-level stock outs of mRDTs or some AL formulation in the past year were reported by 66% of supervisors. Use of CHW kit materials by health facilities was reported by 43% of supervisors; this was most common at facilities experiencing stock outs. The study concluded that, variations in geographical and seasonal malaria commodity needs should be considered in CHW kit distribution planning in Mozambique. Improvements in the provision of complete, monthly CHW kits are needed in parallel with improvements in the broader commodity system strengthening. The findings of this evaluation can help other CHW programmes determine best practices for management of supply chains (41).

In Kenya, a study was conducted to ascertain the factors influencing frequent stock-outs of essential medicines in public health facilities in the country concentrating on facilities in Kisii county. The study adopted a descriptive-survey design with stratified, random sampling from a sample comprised of 30% of the target population or 105 public-health administrative staff members of a target population of 351 administrators from the nine sub-counties of Kisii. Information was gathered using questionnaires, observation and interviews. The findings of the study indicated that a 49.1% change in the availability of essential medicines could be attributed to independent variables. Information communication technology (ICT) was determined the most important factor, followed by inadequate staff qualifications, supply-chain design and monitoring and oversight mechanisms, respectively. The study recommended that the Kisii county government

institute policies that would ensure functionality of the study factors considering that ICT was being used for conventional purposes of filing, but not for decision-making concerning medication management. Poor staffing was evident based on unmatched skills placement as well as the existence of a reactive supply-chain design signaling poor control (42).

The study was conducted to establish how supply-chain factors affect product availability at the community level, the study document, Improving Supply Chains for Community Case Management of Pneumonia and Other Common Diseases of Childhood Project developed a hypothesis of change (TOC) framework for gathering, organising and interpreting evidence relevant to supply constraints in community-case management (CCM). Baseline assessments in Ethiopia, Malawi and Rwanda, conducted in 2010 provided information on the strength and weaknesses of existing CCM supply chains for five products: antibiotics for pneumonia, an oral rehydration solution, a therapeutic fast-food, zinc and artemether/lumefantrine. The assessments tested the effectiveness and validity of causal pathways identified in the TOC that were thought to determine the availability of CCM products among community health workers (CHWs) for treating common childhood maladies. The findings indicated poor product availability in each country, with more than half of CHWs stocked out of at least one tracer product on the day of the assessment. This study focused on the findings related to three key preconditions of the TOC and how these were used to inform the design of the CCM supply-chain improvement strategy in each country. The three key preconditions include product availability at CHW resupply points, supply-chain knowledge and capacity

among CHWs and their executive programs, and availability of appropriate transportation (43).

A study conducted in India examined the impact of drug stock-outs at public health facilities based on retail price and the quality of care received by customers in the private sector. The study identified the effect of competition by exploring exogenous fluctuations in drug stocks at public-sector health facilities based on centralised delivery schedules. The study compared outcomes before and after scheduled delivery dates to local markets with or without public-sector facilities. The findings showed that during stock-outs, private-sector customers paid higher (often widely varying) prices on average and were more likely to purchase ineffective malarial drugs, though there was no significant change in the quality of drugs received, measured with spectrometer testing. There was some evidence of price discrimination by customer demographics. Those with lower levels of education and income appeared more likely to drop out of the market in response to stock-outs. Frequent stock-outs in the public sector may lead to poorer, less equitable outcomes for patients in the short run and higher equilibrium price levels in the private sector in the long run (44).

A descriptive study conducted in northern Rwanda assessed the level of stock-outs and whether the distance to a district pharmacy, supervisor visits or delays in drug delivery from district pharmacy to health centers were associated with stock-outs in 15 rural health centers in northern Rwanda. Data was extracted from stock cards, dispensing records and health-center registers. One tracer drug, mebendazole, experienced no stock-outs. Artemether-Lumefantrine and nevirapine syrup were the most affected medicines subject to stock-outs with an average period of 10.5 months at 10 health centers. No

correlation was discovered between drug stock-out and distance, supervisor visits or delays in delivery. An hypothesis were formulated that the observed stock-outs could be attributed to the availability of different dosages of the same medicine, special orders made during campaigns, staff turnover and logistical issues beyond health centers' control, such as delays in importation. These studies should be reviewed more deeply in future research (45).

2.2.2 Challenges of mRDT utilization and implementation.

Malaria Rapid diagnostic Tests (mRDT) for malaria enable diagnostic testing at primary care facilities in resource-limited settings, however there are some challenges of utilization and implementation of mRDT (41).

The study conducted in Ghana aimed to identify the factors directly influencing malaria RDT implementation at primary care facilities in a Ghanaian district. Qualitative interviews, focus groups and direct observations were conducted with 50 providers at six purposively selected primary care facilities in the Atwima–Nwabiagya district. Data were analysed thematically. Results show mRDT implementation was hampered by the following: healthcare delivery constraints (weak supply chain, limited quality assurance and control, inadequate guideline emphasis, staffing limitations); provider perceptions; social dynamics of care delivery (expected norms of provider-patient interaction, test affordability); and limited provider engagement in policy processes leading to fragmented implementation of health sector reform. In conclusion, limited health system capacity, socio-economic, political, and historical factors hampered malaria RDT implementation at primary care facilities in the study district. For effective mRDT implementation providers must be adequately enabled through efficient allocation and management of

essential healthcare commodities; appropriately empowered with the requisite knowledge and skill through ongoing, effective professional development; and actively engaged in policy dialogue to demystify socio-political misconceptions that hinder health sector reform policies for improving care delivery. Clear, consistent guideline emphasis, with complementary action to address deep-rooted provider concerns will build their confidence in, and promote uptake of recommended policies, practices, and technology for diagnosing malaria (41,43).

Another study was conducted in Niger State, in which it explores accessibility barriers to the use of mRDT in Niger State and makes recommendations for improving the uptake of mRDT. The study employs literature review, review of data from the Niger State Health Management Information System, and application of the Peters' conceptual framework for assessing access to health services. Data showed that 27 percent of public health facilities (HFs) implemented mRDT, with the aid of donor funds. In these facilities, 77 percent of fever cases presented during the study period were tested with mRDT; 53 percent of fever cases were confirmed cases of malaria, while 60 percent of fever cases were treated. Stock outs of mRDT were a major constraint, and severe fever tended to trigger presumptive treatment. The study concluded that although implementation of mRDT led to a reduction in the use of Artemisinin Combination Therapy (ACT) at HFs, a more substantial reduction could be achieved if the state government directed more resources towards the acquisition of mRDT as well as raising the level of awareness of potential users (44,45).

2.3 Overview of the Global Health Supply Chain

The global health supply chain (GHSC) is a complex, dynamic network that operates on principles governed by supply-and-demand, created between international companies, organizations, people, actions, data, and resources which are involved with moving essential health commodities. The network processes high-quality medicines, such as the ARV, Nevirapine syrup, diagnostic test kits, such as mRDT, and provides services linking suppliers and customers (32). It is managed with an overview of materials, information and finances as they interact in the chain from supplier to producer to wholesaler to retailer to consumer. The process of managing the GHSC is called global supply-chain management (SCM). It coordinates and integrates factors of supply and demand across a multitude of companies and systems operating in an international environment (32). The GHSC of essential medicines such as ARV and mRDTs is highly sensitive, because a customer service level (CSL) below 100% is unacceptable due to direct impact on health and safety (22).

2.3.1 Global Supply Chain of Essential Medicine and diagnostic test kit

Research has shown that people living with HIV/AIDS are able to lead normal and healthy lives on condition they were diagnosed promptly and receive medication on a continuous basis (33,34). With uninterrupted, antiretroviral treatment (ART) the level of HIV in an infected person's body is maintained at the lowest possible level. Further weakening of the immune system is prevented and life is prolonged. In the case of mRDT, the central role of SCM is to achieve universal coverage of the key malarial intervention, one factor being mandatory testing before treatment, which many countries have recently adopted as policy (35,36). For that reason, the global supply chain of ARVs

and essential diagnostic tests involves delicate processes requiring capital and stakeholder involvement to ensure the flow of these medicines from manufacturers to patients are reliable and efficient.

To cite an example, each year it is estimated that 100 million packs of ARV, at a value of more than one billion U.S. dollars, moves from a handful of manufacturers to recipient countries around the world. In each country, these ARVs are distributed to tens of thousands of antiretroviral treatment sites, and ultimately reaches an estimated 9.7 million patients (37).

Understanding the role of diverse stakeholders, various stages of movement and other activities of the ARV and mRDT supply chain, is vital for the global health community, both to ensure full and efficient treatment of persons living with HIV/AIDS (PLWH) and people infected with malaria, as well as to inform supply-chain decisions that are made on behalf of other public-health products.

There are four, key stakeholders in the distribution of essential medicines and diagnostic test kits, namely manufacturers, funders, beneficiaries and operational agents (32).

2.3.2 Manufacturers of Medicines and Rapid Diagnostic Test Kits

Global manufacturers of medicines, including ARVs and mRDT, are divided into two main classes identified by the drugs they produce, branded (originator) and generic. A brand name medicine is an original formulation, the first of its kind in its pharmaceutical composition. The manufacturer, who produces it, has invested capital in discovery and development of the drug and ensures a satisfactory return on this investment by licensing the drug under patent.

Generic medicines are produced by manufacturers who do not have a patent license on the drugs they produce and who replicate the formulation of a medicine whose patent has expired or is not applicable in the geographical area in which they operate. Brand name drugs are always expensive in comparison with their generic copies. Generic medicines are typically 20 to 90% cheaper than brand name or originator equivalents (37, 38).

The use of generic medicines has increased in recent years, primarily as a cost-saving measure in healthcare provision. The manufacturers of generic drugs are often found in developing countries where brand name drug patents are not applicable due to terms of agreement. Due to the low prices of generic ARVs and mRDT, manufacturers in collaboration with funders or donors have promoted the increasing availability of these drugs in countries that command limited resources (39, 40).

2.3.1.2 Funders of Medicine

Funders and donors play a significant role in shaping the supply chain of ARVs, antimalarial drugs and diagnostic test kits by providing massive funding to recipient countries, by which medicines and diagnostic kits are made widely available. Some countries function both as a recipient and funder, in that they finance (totally or partially) their own procurement and supply of ARV and mRDT (41). Although donors and funders alike set policies to ensure transparency in selection of operational agents, establish quality standards, and tender fair procurement practices, there are key differences between them that produce variations in supply chains. These differences are influenced by donor emphasis regarding country ownership and its associated policies and requirements. The procurement and supply chains of the products they fund will vary

between integrated global supply chains and country-based distributed models supporting country ownership (41).

2.3.3 Distributed Model

In a distributed-model supply chain, donors offer flexibility to a country to head the management of its supply chain and procurement. A country may choose its own supply-chain and procurement partners and is freed to create policies to manage tendering, purchasing, ordering and delivery, as long as they remain compliant with donor-framed requirements (42). Though a supplier may be shared by several countries, procurement and supply-chain management in a distributed model are carried out by countries independently of one another. In this model, synergies and economies of scale are limited. For example, a country with a small population using a specific drug may order small volumes that are well below the size of a production batch.

The distributed model inherently carries the risk of creating undesired competition among countries as their procurement agents compete with each other for available stocks and suppliers quote differentiated prices to different buyers (42). This competition can create problems for small purchasers whose volumes may not be attractive to global suppliers, and consequently lead to failed tenders or higher pricing. Countries that receive funding from the Global Fund are more likely to operate under this model, than countries funding their own ARV or mRDT (43). Many west-African countries operate using the distributed model that receives funding from the Global Fund, as well as fund themselves. These have a national procurement agent, potentially contracted out to a specialised agent, who performs all procurement agent functions from tendering to delivery. Utilising this model, countries have a high degree of control and ownership over

procurement. However, this control may come at the cost of relinquished efficiency and supply stability that would be achievable with an integrated model (44).

2.3.4 Integrated Model

In a fully integrated model, such as employed by the American President's Emergency Plan for AIDS Relief (PEPFAR), and the Supply Chain Management System (SCMS), procurement activities is carried out on behalf of countries. The donor contracts, services directly. These may include tendering, order placement, warehousing, clearing and other related activities in several countries (45).

Through this method, procurement agents manage orders for various countries and may aggregate orders to achieve supply and price benefits. For example, integrated procurement models may include global or regional warehousing of pre-purchased ARVs, which can be sourced to buffer emergency orders or access alternative methods of shipping to reduce costs (9). To support country ownership of a treatment programme, orders and deliveries are directed by country-level quantification and supply-management plans. In addition, by pooling demand to increase volume, a procurement agent can achieve greater leverage with suppliers for reduced prices and ensure availability of products for all clients. Particularly in periods of supply constraint, when 'rationing' is necessary, all clients can be assured they will benefit from limited supplies, helping them avoid supply interruptions (9).

In most countries that receive PEPFAR funding, SCMS will manage the procurement and supply-chain processes by default, at least by delivery in-country. The SCMS will supply from regional warehouses, whose inventory was pooled transported with sea freight

which is less expensive than air freight. Likewise, SCMS directly engages in supplier selection and negotiation, signing agreements with manufacturers (46).

2.3.5 Beneficiaries of mRDT and NVP syrup.

Globally, a recipient country and associated partner networks involved with delivering malarial products and HIV-care are described as beneficiaries. Before orders are placed, recipient countries and their partners determine the products and volumes, the timing of orders, and set lead time expectations. In addition, national policies, treatment guidelines, product registration, import requirements and other factors will influence how procurement and distribution are carried out (46). After receiving an order, a beneficiary will manage its country's internal supply-chain system, which often consists of storage (warehousing) at a Central Medical Store (CMS), transport to regional distribution centers, and distribution to clinics, health centers and ART sites where patients receive treatment (47). Depending on the funding source and related agreements, beneficiaries may control their own procurement and supply-chain processes from manufacturer to patients. A growing number of governments in beneficiary countries are making contributions toward funding of ARV and mRDT from internal revenues. This variation can complicate the task of coordinating procurement and supply management (48).

2.3.6 Operational Agents for mRDT and NVP syrup

The management of supply chains from manufacturers to patients requires specialised skills in the timely and efficient delivery of quality mRDT and NVP syrup (49). Operational agents include procurement agents, companies that forward freight, customs brokers and carriers, as well as government-managed operators. Procurement agents represent the umbrella organisation responsible for contracting with many of these

operational partners, whose activities commonly include order placement, tracking and execution, supplier selection, negotiation and performance management, pre-shipment quality control, and logistics per agreed international commercial terms and documentation (5). Although the function of procurement agents is largely transactional, the implementation and the resulting shape of the supply chain may differ substantially based on the terms of contracts with donors and beneficiary countries (49). The procurement agents involved in the supply of ARVs and RDT include national procurement agents, who procure product on behalf of their country.

After medicines have been procured, a freight forwarder, also known as a non-vessel-operating common carrier (NVOCC), organises shipments to get medicines from the manufacturer or producer to a market, customer or final point of distribution (42). Forwarders contract with a carrier, or multiple carriers, to move product. A forwarder does not move product himself, but acts as a logistics expert in the network. These carriers employ a variety of shipping modes, including ships, airplanes, trucks and railroads, and often engage several modes for a single shipment. For example, the freight forwarder may arrange to have cargo moved from a plant to an airport by truck, flown to its destination, then arrange transport from the airport to a customer's storage facility with a truck (50, 51).

2.4 Supply Chain in Africa and Stock Levels

Efficiency in public-health supply chains is essential to assure access to health supplies and consequently for favorable health outcomes. Efficiency is particularly important in countries in sub-Saharan Africa, where large populations are served by public and mission, health sectors (52). African countries take approaches to supply chains that

ensure efficiency and effectiveness in their operation. These include a primary-distributor-model approach, whereby a government contracts companies to manage the pharmaceutical supply chain, while it provides contractual oversight and control procurement procedures. A different approach engages individuals or non-governmental organisations to supply a specified area or specific health facilities (53). Innovative public-private relationships have been established in various African nations, including Zambia, South Africa, Tanzania, Kenya, and Uganda.

These approaches are enjoying increased donor funding, by donors who demand development of integrated systems in the supply chain that fully utilise the capacity of public, non-governmental and commercial sectors. However, weak links in the health supply chain continue to greatly restrict access to essential health products, including those needed to prevent and treat AIDS and malaria (54). Weaknesses in the health supply chain in Africa have been responsible for stock-outs of medicines and have been revealed in the findings of studies conducted in African countries.

A cross-sectional study, using structured interviews was conducted in Kinondoni district, Dar es Salaam, Tanzania, investigated stock-outs of ARV drugs and the coping strategies employed to prevent changes in treatment regimens in HIV/AIDS care. The study showed that stock-outs of ARV drugs were reported in 16 out of 20 clinics, forcing 210 patients to change their ART regimens, during a 12-month period preceding the survey. Inefficient supply systems, quantification problems and short expiry duration were cited as the main causes of stock-outs. The coping strategies utilised to prevent changes in ART regimens included shortening the refill period, borrowing stocks and moving patients to other clinics (55).

The study concluded that changes in ART regimens due to stock-outs occurred in a small but significant number of patients. Changes in regimen increase the risk of the emergence of drug-resistant HIV strains. Health-care workers use various coping strategies to prevent changes in ART regimens, but unfortunately, some of these strategies are likely to increase costs which must be carried by patients. This eventuality may discourage patients from appearing at their clinic, leading to unplanned treatment interruptions (27).

Another study was conducted in Tanzania to determine the pattern of availability of mRDT and the possible causes of observed stock-outs at public-health facilities. Data was collected weekly with a mobile reporting tool, 'SMS for Life', on mRDT availability at over 5,000 public health facilities in Tanzania. The findings indicated that over a period of 15 months, on average, 29% of health facilities in Tanzania were completely stocked out of mRDT with a median to total stock-out of six weeks. Occurrence of total stock-out by region ranged from a low of 9% to a high of 52%.(56).

The mRDT stock-outs were most likely caused by irregular patterns in mRDT supply (several months with no stock) and an insufficient supply entering Tanzania. It was concluded that the reduced mRDT availability and irregular pattern of supply were due to cumbersome, bureaucratic processes and delays within the country and on the part of the primary donor, Global Fund to Fight AIDS, Tuberculosis and Malaria. It was recommended that Tanzania invest in strengthening both the supply system and the health information system using mHealth solutions such as 'SMS for Life'. These measures could assist tracking RDT availability throughout the country and encourage the partners to work towards more streamlined, demand-driven and accountable procurement (55).

A cross-sectional survey, complemented with a qualitative method, was conducted in public-health facilities in Ethiopia (four hospitals, 20 health centers) of supply-chain management of HIV/AIDS related commodities, revealed that more than three quarters of the health centers placed one or more emergency orders of ARV medicine on the day of the visit, while all hospitals had placed emergency orders more than three times in the six-month period prior to the study. All of the hospitals, and nearly half of the health centers, had made emergency orders of test kits more than three times in the previous six months. Overall, nearly three quarters of the health facilities faced stock-out of one or more ARV medicines and test kits on the day of the visit. Adequate data on patient medication record and stock status of HIV/AIDS related commodities was not available. Moreover, frequent stock-outs of ARV medicines and HIV test kits had occurred, an indicator of weak supply-chain management. Hospitals and health centers were advised to devise systems of capture that would make use of patient medication records and stock-status information to ensure continuous supply of the commodities (5).

A longitudinal cross-sectional study on the shortage of mRDT was conducted in Mozambique, which evaluated drivers of stock shortages of mRDT in the Cabo Delgado province. In this study data was collected from purposively sampled health facilities, using monthly cross-sectional surveys between October 2011 and May 2012. Estimates of lost consumption (missing consumption due to stock-outs) served as primary quantitative indicators of stock shortages. These estimates are a better tool for measuring the magnitude of stock-outs than binary indicators which only measure the frequency of stock-outs at a given facility. Using a case-study based methodology, distribution system characteristics were qualitatively analysed to examine causes of stock-outs at the

provincial, district and health-center levels. The study was conducted at 15 health facilities at 120 points in time. Stock-out patterns varied according data sources. Average monthly statistics indicated 59%, 17% and 17% of health centers reporting stock-outs on stock cards, and laboratory or pharmacy forms, respectively. Estimates of lost consumption percentages were significantly higher, ranging from 0% to 149%, with a weighted average of 78%. Each ten-unit increase in monthly-observed consumption was associated with a nine-unit increase in lost consumption percentage indicating that higher rates of stock-outs occurred at higher levels of observed consumption. Causes of stock-outs included inaccurate tracking of lost consumption, insufficient sophistication in inventory management and replenishment, and poor compliance with processing procedures by facility workers, all arguably stemming from inadequate attention to the design and implementation of the distribution system. In conclusion, substantially high levels of mRDT stock-outs were found in Cabo Delgado. Study findings pointed to a commendable degree of sophistication in the supply chain. However, insufficient attention was dedicated to the system design and implementation, resulting in deteriorating performance in areas of greater need. In such settings, fast-moving commodities like mRDT call attention to supply-chain vulnerability, the discovery of which can be used to address other slow-moving health commodities (56).

A study carried out in Niger state, Nigeria, explored accessibility barriers to the use of mRDT in Niger and made recommendations to improve uptake of mRDT. The study ran a literature review, a review of data from the Niger State Health Management Information System (January–October 2013), and applied the Peters' conceptual framework for assessing access to health services. Data indicated that 27% of public

health facilities (HFs) implemented mRDT with the aid of donor funds. In these facilities, 77% of cases of fever presented during the study period were tested with mRDT, 53% of fever cases were confirmed to be malaria, while 60% of the fever cases were treated. Stock-outs of mRDT were a major constraint, and severe fever in the cases seen tended to trigger presumptive treatment. We concluded that, although the implementation of mRDT led to a reduction in the use of antimalarial medicine at HFs, a more substantial reduction could have been achieved had the state government directed more resources towards acquisition of mRDT as well as raising the awareness of its potential (57).

In Kenya a cross-sectional survey was carried out to investigate mRDT availability in government facilities in seven malaria-endemic districts. One of four of the surveyed facilities had no mRDT in stock; three in four facilities were out of stock of at least one mRDT pack, leading health workers to prescribe antimalarial medicine without testing for the disease. The shortage was in large part due to a delayed procurement process. National ministries of health and the international community need to address shortfalls of mRDT supplies in the public sector (58).

2.4.1 Strategies to Improve Health Supply Chain in Africa

A public health supply chain system in sub-Saharan Africa requires a different mind-set when thinking about how to improve and deliver successful change. Experience in sub-Saharan African countries have shown that public health supply chains in Africa are not short of complexities; one has to balance government bureaucracy, new technique, individual donor interests, public private partnership, vested interest and the influences of the wider political economy to deliver a high performing supply chain. There are some studies done which showed how the health supply chain in Africa can be improved.

The evaluation study was done in Kenya to find out the effectiveness of the short messaging system (SMS) in reducing the stock out of malaria rapid diagnostic test (mRDT). The study included more than 80 public health facilities in the country. Every week the stock status of mRDT was reported via SMS from a health worker at health facility to the district health manager. The results indicated that the response rate was more than 95%, while the accuracy reports of stock out of mRDT were 93%. District health manager responded from the SMS reports by redistributing mRDT between the health facilities, the redistribution rate to prevent stock out was more than 70%. In conclusion the use of SMS technology in this study showed the declined of the trend of stock out were significant (18).

Furthermore, research has shown that the private sector subsidy program of mRDT and antimalarial have been effective in increasing the availability of anti-malaria and malaria diagnostic test kits in the private sector and cutting down the prices of this medicine and its diagnostic test kits. Therefore, it was recommended that a subsidy of mRDT in the private sector is necessary in order to prevent over treatment with antimalarial which can cause wastage of resources, also subsidy can prevent emergence of resistance of antimalarial and control increase of morbidity and mortality due to malaria (59).

In sub-Saharan Africa, the key lesson from the HIV experience has been to amend the preparation and content for supply chain management and maintenance of buffer stocks of medications. Currently, the “Stop Stock-Outs” program has been initiated in which local health personnel and community volunteers report the availability of a list of primary care (60).

2.5 Health Supply Chain in Namibia

Health supply chain in Namibia aims to improve the health of all Namibians by increasing the availability, accessibility, affordability, and appropriate use of essential medicines and health supplies. To accomplish this, Namibia health supply chain (NHSC) has three key pillars. Firstly, to ensuring that national policies support cost-effective, equitable, and transparent use of essential medicines and health supplies. Secondly, strengthening country capacity for the effective management and utilization of essential medicines and health supplies. Thirdly, increasing the availability and access to essential medicines and health supplies for priority populations (61). Namibia health supply chain develops and implements interventions to strengthen Namibia's supply chain system, expand effective management practices, build in-country capacity, and improve financial and information management systems, all of which support increased access to essential medicines including NVP syrup and malaria rapid diagnostic test (mRDT) (31).

2.5.1 Waste in Essential Medicine Management in Namibia

Wastage of essential medicines in Namibia is not well documented, but there are some reports and anecdotal evidences which show a lot of essential medicines are wasted due to the various reasons or factors as illustrated in Figure 2. According to World Health Organization (WHO) (62-64) define quality of care as “the extent to which health care services provided to individuals and patient populations improve desired health outcomes. In order to achieve this, health care must be safe, effective, timely, efficient, equitable and people-centered.” Here efficiently refers to deliver health care in a manner that maximizes the resource use and avoid waste

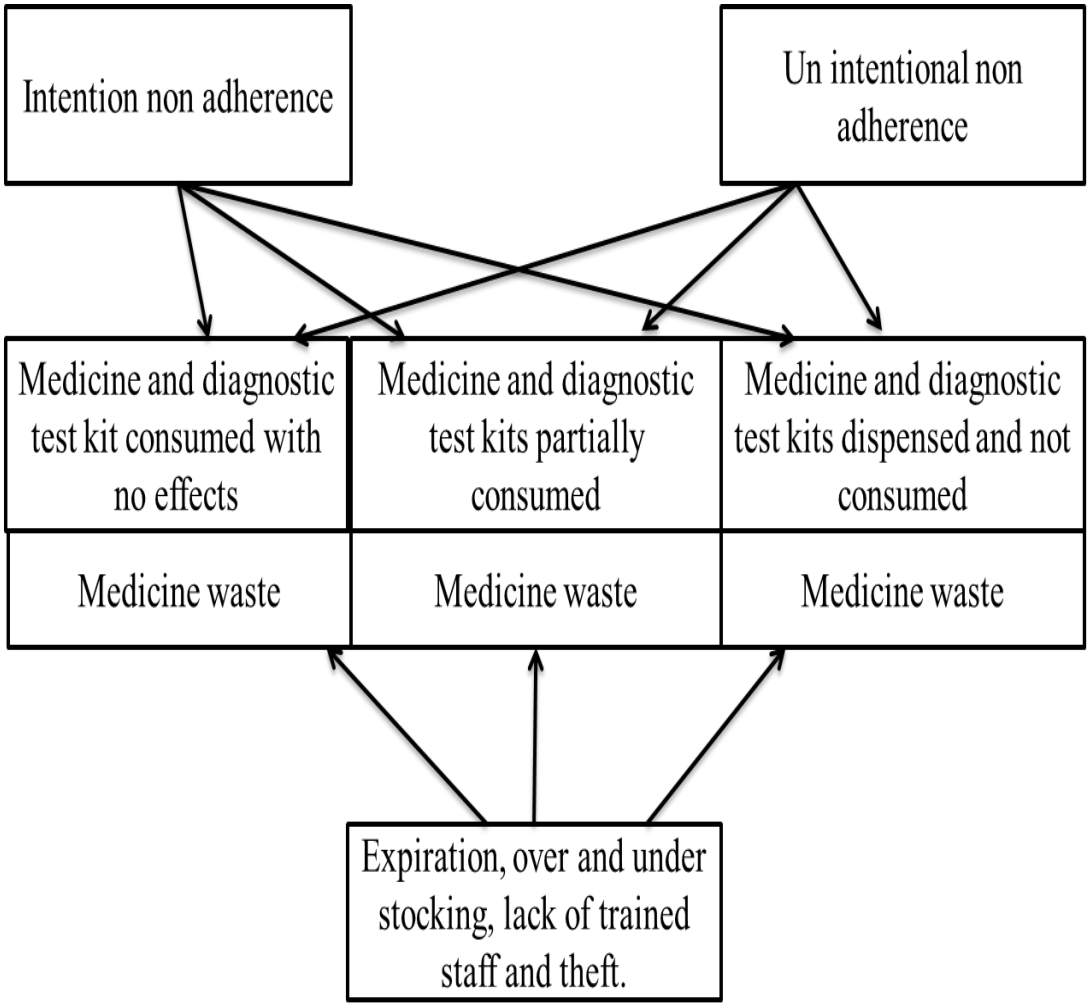


Figure 2. The causes of waste of essential medicines in Namibia as adapted and modified from Managing Access to Medicines and health Technologies (63).

Figure 2 illustrated that theft, oversupply, lack of trained staff and poor quality has been reported in various health facilities across the country as a source of essential medicines waste. Theft in health facilities is due to lack of proper security procedures in the storage areas, especially in health centers and clinics whereby many health workers in those facilities have access to the storage areas, this increase the chance of medicine theft hence wastage. Shortage and lack of trained staff has been identified as a source of wastage of essential medicines due to lack of knowledge in ordering, storage technique, as

pharmaceutical services in health centers and clinics are managed by nurses who were not well trained in pharmaceutical management and logistics (28,64).

Other challenges include under stoking, which is a very serious issue as it can lead to a loss of sales, customers or patients. If a patient or a customer visit hospital or health facility and desired medicines are not available, the patient will search out alternatives and be forced to go to other places such as traditional healers, sharing of medication or refuse to search for alternative and decide to stay without medicines as a result health condition of the patient will deteriorate. Over stoking is not optimal either because it has three types of costs, namely financial, physical and obsolescence (65,66). In financial costs, more money will be in inventory instead of profitable business or services, while physical costs, is due to the shortage of space due to overstock or hire the space for storage. The physical cost can reduce the quality of medicines. The least cost due to over stoking is obsolescence cost, this refers as a large amount of inventory for medicines that get low consumer demand or the demand is highly fluctuating. Such medicine may not be able to satisfy the consumer (65).

Changes in financial markets and political turbulence, socio-cultural, and finally the growing requirements of consumers become the cause of unexpected distortions. In turn, it promotes the occurrence of loss. These affect both individual patients, as well as the entire network of supply chain in the organization (64). Wastage can also caused by the users (patients) because of tradition or religion beliefs. Some patients will stop taking medicines because they no longer believe that medicines can cure or prevent progression of diseases or they can stop taking medicines by believing in traditional medicines (34).

2.5.2 Potential for Improvement

Namibia through MOHSS management is working with the Regional Medical Depots (RMD) and Central Medical Store (CMS) and other stakeholders who are strongly involved with medicines such as regulators, international organizations, journalists, purchasers, prescribers, program managers, policy makers, public health actors and the patients. Advocacy should be research based and monitoring programs. Technical concepts should be translated into simple, understandable language through communication tools that address all the stakeholders (45).

Reducing medicines waste will improve quality, save resources and allow staff to focus on the roles that add value to patient care. There is a need and an opportunity for strong leadership from pharmacists to help reduce medicines waste.

2.5.3 Namibia Approach

The uninterrupted supply of antiretrovirals (ARVs) including NVP syrup is key to realizing health outcomes and targets of the government of the Republic of Namibia. With support from donors and other funders which aimed by scaling up HIV treatment in specific priority regions in the country where the burden of the HIV epidemic and the unmet need for ARV treatment are highest, these priority regions include Oshana.

Namibia also seeks to be the first country in the region to eliminate mother-to child-transmission of HIV. Donors and funders also provide technical support to the Ministry of Health and Social Services in areas such as warehousing, transportation, procurement activities from the tender process to contract and financing in order to bring maximum impact on preventing AIDS, Tuberculosis and Malaria. For AIDS/HIV this support also

focused on revising ARV forecasts so that to accommodate the 90-90-90 goals, the use of the Ministry of Health and Social Services (MOHSS) pharmaceutical information dashboard to improve forecasting and supply planning for ARVs and related pharmaceutical products and improve access to pharmaceuticals and promote data analysis and use interpreted data for decision-making at the national and regional levels. Donors, funders and other stakeholders working directly with the MOHSS's pharmaceutical division, technical programs, district management and care facilities in all regions in Namibia to achieve program activities and results (61,62).

2.5.4 National Drug Policy and Legal Framework for Namibia

The availability of safe and effective essential medicine and diagnostic test kits are an important condition for well-functioning curative and preventive health services, in addition to availability, accessibility and affordability for people in need as well as an appropriate use of health workers and patients (63). This policy address all main components which impact on the functioning of public and private pharmaceutical sectors, such as legislation and regulation, drug procurement, distribution, appropriate use of drugs by health workers and consumers, human resources development and drug pricing and financing (31,63). The policy is based on the geographic, demographic, economic and social conditions prevailing in this country and on the characteristics of the national health sector and the pharmaceutical sector. There are several aims of this policy. One of the main aim is to ensure that essential drugs of high quality are available in adequate quantities to meet the health needs of the population in all parts of the country at the lowest possible cost (63,64).

The policy also gives the guidelines on drug procurement for the public sector. It is indicated that the procurement will be carried out by Central Medical Stores (CMS), based on an international tender system. Evaluation and adjudication of tenders will be conducted by the respective tender committees and final approval given by the Tender Board of Namibia (4). In emergencies, or where circumstances dictate otherwise, drugs may be procured through direct buying from suppliers, by quotation in compliance with Tender Board Regulations, or by price negotiations and will be procured by generic name based on the Namibia essential medicines list (13,63). The WHO Certification Scheme for Pharmaceutical Products moving in the International Commerce will be used to expedite evaluation and procurement of essential drugs (4,63).

According to the policy all drug donations must comply with the Namibian Policy on pharmaceutical donations and donated drugs must meet all the following criteria be certified by the medicines regulatory authority (MRA) of the exporting country according to the WHO Certification Scheme on the Quality of Pharmaceutical. Donated medicines should have at least 12 months shelf life remaining be labeled in English. All medicines donated to the public sector shall be channeled through the CMS and should not be sent directly by donors to the institutions (61). In case of medicine storage, the MOHSS ensure the provision and regular maintenance of adequate sized, suitably constructed and equipped storage facilities at every level in the decentralized public sector drug distribution system (63). The quality of stored drugs will be checked regularly at all levels in the private and public sectors to ensure that they have not deteriorated under the storage conditions prevailing at each location, and to ascertain the adequacy and suitability of the storage facilities (13).

Inventory Control will be improved and standardized inventory control procedures at all levels of the public drug supply system will be striving through the MOHSS. Minimum and maximum stock levels will be introduced and systematic stock rotation ensured. Proper procedures will be implemented to assure accountability at all levels. Suitable computerized inventory control methods and equipment will be introduced at central and lower levels and staff trained in their use at the earliest feasible opportunity. The MOHSS will introduce and maintain systematic, practical and accurate procedures for the estimation and regular reporting of drug consumption at all levels so that these data can be used in the compilation of estimates for national drug procurement needs and for monitoring drug expenditure (63).The policy indicated that drugs will continue to be distributed through the public, parastatal, and private sectors. The CMS is responsible for the distribution of drugs to the public health sector, according to the Nemlist (61,63).

Also the policy will ensure, the Government will endeavor through the MOHSS to maximize coordination between the different sectors in the transportation and distribution of essential drugs, particularly to less accessible areas of the country. The MOHSS will strive to provide adequate and appropriate transportation and communication facilities and the personnel necessary to maintain an efficient public sector distribution system. The MOHSS will ensure that the decentralization of the public sector distribution system is rationally and efficiently implemented (31).

The MOHSS will institute an efficient and practical system for the identification, collection and redistribution of excess stocks of drugs and medical supplies. Expired, damaged or banned drugs will be disposed of in a way which precludes their use by any person, and with minimal environmental pollution. The MOHSS will encourage the

establishment and extension of private pharmaceutical services to underserved communities (31,63).

2.5.5 Public and Private Health Sector Supply Chain in Namibia

Namibia operates in integrated pharmaceutical supply chain whereby the MOHSS through central medical store (CMS), coordinate the procurement, storage and distribution of all pharmaceuticals and related supplies for use in public health facilities in the country (61). The range of product categories handled by the CMS includes Antiretroviral, malaria medicines and diagnostic test for HIV and malaria.

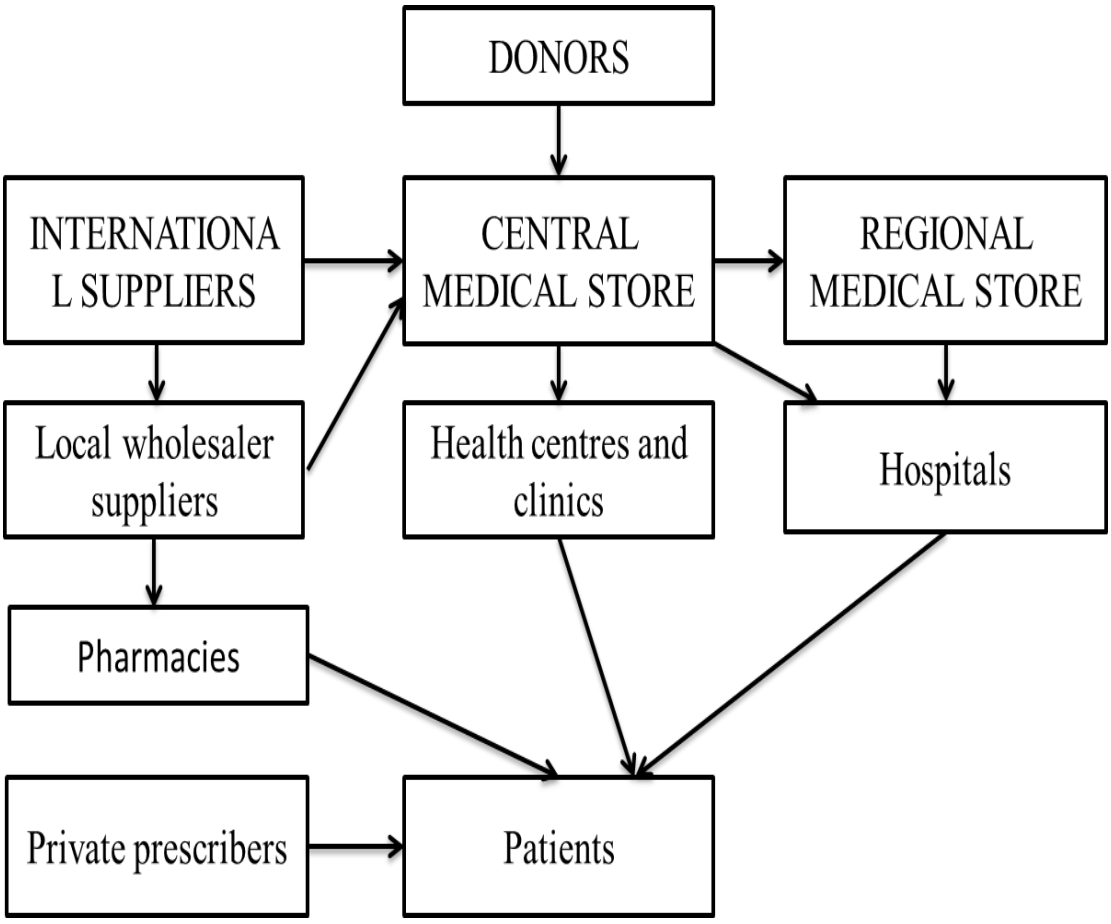


Figure 1. Public and private Sector Supply Chain Diagram in Namibia as adapted and modified from Namibia National Supply Chain Assessment: Capability and Performance (31)

The Ministry of Health and Social Services currently manages approximately 475 public health facilities in Namibia including 35 hospitals, 43 health centers and about 400 clinics. The Central Medical Store (CMS) distributes directly to about 45 health facilities on a six-weekly cycle, including 26 of the 34 district hospitals around the country and the two Regional Medical stores (RMS). One RMS is in Oshakati and the other one in Rundu (31).

The Oshakati RMS (ORMD) serves up to 87 facilities in four northeast regions (Oshana, Ohangwena, Oshikoto, Omusati) while Rundu RMS serves 32 facilities the northeast regions of Kavango and Zambezi (previously Caprivi). In case of a stock out at the CMS and eventually to RMDs, the hospital can get supplies from private hospitals by following buy out procedures as indicated by the MOHSS (63).

2.5.6 Health Supply Chain in Oshana Region

In the Oshana region, health centers and clinics are ordering and receiving medicines from Oshakati RMD (OMRMD) on a monthly basis. But other facilities can order in a two weeks basis depending on the storage capacity at the HF. During the stock taking which is done by the OMRMD in March or April of each year, all health facilities in the region are required to order mRDTs and NVP syrup from Oshakati RMS for the period of two months. The health centers and clinics can place interim/emergency order in case the medicines ordered will not reach the next ordering cycle. It is recommended that the interim order should be kept to a minimum (65). To achieve this pharmacist or pharmacist assistant must ensure that scheduled orders are comprehensive and all required items are ordered in a right quantity. Telephonic orders from the HC or clinic can be accepted in case of extreme urgency. If there is no a pharmacist or pharmacist assistant, nurse in charge or medical doctor can place an order (65). Hospital like IHO supplied by CMS but also can receive supplies from Oshakati RMS in case of emergency orders. Health facilities order or issue to/from other health facilities, if there is a shortage and that particular medicine is out of stock at the RMD (31,37). Sometimes it can be available at the medical store, but because of the transport logistics and other administrative issues at Oshakati RMD, health facilities can order medicines for a very

short period of time from the other health facility while waiting to receive its monthly order from Oshakati RMS.

In Oshana region, NVP syrup is ordered in special ordering form for and mRDT is ordered in a general ordering books. These ordering forms and book were designed by a region pharmacist in collaboration with other staff from Oshakati RMD. Before ordering, a pharmacist or pharmacist assistant should do physical stock, if the stock is at the minimum level, then a pharmacist can place an order and if it is at the maximum level, the medicines should not be ordered therefore order quantity should not exceed the maximum level (65). For the facilities with electronic dispensing tools (EDT) software, a pharmacist can check all details required for ordering on the quantification page of EDT. The ARVs order form consists of the column of stock code, item description, unit of issue, stock on hand, quantity to be ordered and quantity issued from medical store, other information is institution name and code. The duration of time from the day of submitting an order to the day of receiving should not be more than five days. In other cases, duration can take more than a week due to some difficulty in logistics of supply chain. The medicines are transported using the government vehicles driven by the authorized drivers. The driver who transports medicines should also accompany dispatch note and, delivery note or pick slip if the delivery note is not yet available and invoice (Appendix 5). Upon receiving the stock from medical store, the pharmacist or pharmacist assistance must check if boxes are sealed and compare the number of boxes with that indicated in the dispatch note in the delivery note is the same as signing the consignment.

2.6 Stock Level Management

Management of stock level of rapid diagnostic test kits and essential medicine, which includes mRDT and NVP syrup, respectively is the process of oversight, information, and finances as mRDT and NVP syrup move in a process from supplier to manufacturer to wholesaler to retailer to consumers (37). Management of stock level involves coordinating and integrating these flows both within and among health facilities. It can be divided into seven stages as indicated in Figure 4 below. Each stage is completed with monitoring and evaluation throughout, to ensure the efficient supply chain function and uninterrupted supply of essential medicines and rapid diagnostic test kits to patients (7).

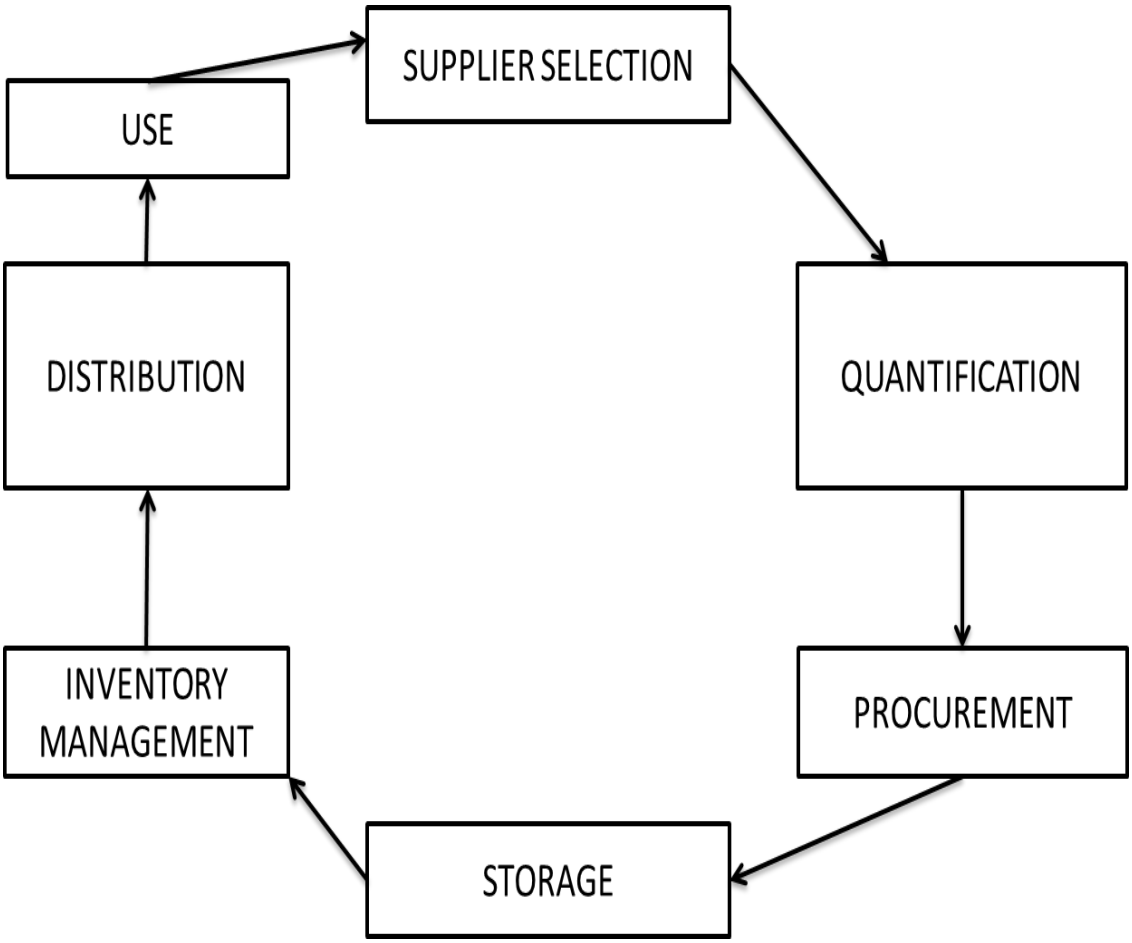


Figure 4. Supply chain management cycle adopted from ARV and RDT procurement and supply chain management (37).

2.6.1 Supplier Selection

Essential medicines in this case NVP syrup and RDT which is mRDT being selected based on the need and potential suppliers are evaluated and selected based on criteria such as diversity of supply, pricing, quality, compliance with quality standards and facility level, medicine availability and logistics management (5,41). Items selected must be chosen in compliance with national Standard Treatment Guidelines (STGs) of that country and tender procedures. Given the shared emphasis on fairness and transparency in supplier selection, many donors stipulate global tendering, and for supply stability,

certain donors also directly engage manufacturers with long term price contracts (66). The institution, most common CMS in many countries shares information in a structured way about what it wishes to buy, including volumes, quality expectations and delivery expectations, then suppliers provide an equally structured proposal including information on their capabilities and quality management systems, pricing and related terms of service. The tactics by which stakeholders choose suppliers can influence the dynamics of the market and supply chain (5,41,66).

2.6.2 Quantification

Quantification is the first step in the procurement process. In general terms, quantification is the process used to determine how much of a product, i.e. essential medicines and rapid diagnostic test are required for the purpose of procurement. But more specifically, quantification involves estimating not only the quantities needed of a specific item, but also the financial means required for purchasing the item. Needs are estimated for a given context, and the analysis must include contextual factors, such as available funds, human resource capacity, health program, e.g., HIV and malaria program, storage space capacity, and capacity to deliver services (37,54).

There are several methods which can be used in quantification, namely the consumption method, morbidity method, proxy consumption method and service level quantification. The quantification method must be chosen in light of the resources and information available (95). The consumption method, which uses data on medicine consumption, gives in many instances the most accurate prediction of future needs. Large, well-established pharmaceutical supply systems rely primarily on the consumption method. To be reliable, the consumption data must come from a stable supply system with a

relatively uninterrupted supply and a full supply pipeline. In case there is no reliable information available on the past consumption or morbidity, the consumption can be extrapolated from data for other health facilities, region or country with some similarities, consumption data may or may not reflect rational prescribing and use of medicines or actual demand for medicines (50,54). If shortages of medicines have been widespread, quantification estimates must be adjusted because the supply pipeline must be filled. The lead time has a major effect on the quantities required for safety stocks. In virtually all supply systems, adjustment is necessary for losses caused by wastage and theft (50,54). Quantification estimates can be cross-checked by combining different methods. No matter which method is used, a gap may exist between the initial estimates of medicines needs and the allocated budget. The quantification process itself may help justify an increase in the budget, but often the quantification estimates must be adjusted and reconciled to match available funds. Quantification can be centralized, or it can be decentralized to staff of peripheral warehouses, and health facilities (67). The personnel and time requirements depend on the quality and accessibility of source data and on the type and scope of quantification. In Namibia the quantification of medicine is centralized (67).

2.6.3 Procurement

Procurement plays a critical role in ensuring the availability of mRDT and NVP syrup at all times and at an affordable price for the people that need them (40). It is one of several stages of the drug management cycle, which involves many stakeholders who can affect it or whose work can be markedly changed by it (50). In the procurement of essential medicines and rapid diagnostic test one needs to consider their key characteristics and

also address specific needs of that institution/health facility (50,68). For instance RDT kit has special characteristics that influence how they are managed, such as shelf life, packaging, and cost. Thus, they may require special handling or modifications to the existing supply chain (67). Furthermore, malaria and its control have unique characteristics, such as seasonality, heterogeneous transmission, and a history of treatment provided at the community level. The particular nature of the disease, and related services and products, influence supply chain management for HIV/AIDS and malaria (68).

Normally procurement commences with the formal request for tender, or bid, which is submitted to the purchaser or their procurement agents, who adjudicates the best value bid and then orders the appropriate quantities and types of ARV or RDT from the selected supplier. There are several key tasks in procurement which can be grouped into several classifications, namely transparency**,** which must be done in a manner that ensures transparency and a corruption-free process (48). Transparency and adequate reporting build trust and ensures that the relationship between implements and governance organizations are mutually supportive (68).

Cost containment dictates that the procurement of pharmaceuticals receives special attention to contain costs and purchase to maximum effectiveness and technical capability which help to ensure expectations of the various stakeholders that drugs will be available at all times, at the lowest cost, and be of acceptable quality and efficacy and that patients will receive all their medicines in a timely and appropriate manner (67).

Patient safety is recognized as a key task in procurement a priority for health care organizations and is receiving increased attention. Purchasing for safety should therefore be a guiding principle for medicines procurement. Adhering to an appropriately selected drug list is another task which based on the hospital's formulary or national drug list prepared by an appropriate body, such as a multidisciplinary hospital drug and therapeutics committee (67).Similarly, systematic management and assessment of drug use should be conducted using clinical judgment. The selection process can be affected by changes in the drug market, therefore sharing accurate information among staffs and among procurement trading partners is necessary for productivity, effectiveness, and efficiency in the health facilities. This aids in the effort to control costs and helps the health facilities to ensure that enough supplies are at hand and that stock-outs are minimized. Records and documentation can be kept in a number of ways. Human error can be reduced and data processing improved by the use of telecommunication and computer technologies, which should be introduced when available and appropriate (69).

In addition to quality-assurance activities that are conducted by individuals involved with procurement, each hospital or procurement agents should develop and implement its own internal quality-assurance system. This will minimize substandard, counterfeit and contaminated medicines. Proper budgeting and financing is necessary for successful procurement and careful quantification, and planning will ensure that the pharmacy can request adequate funding to procure the necessary medicines (69).

2.6.4 Storage

Storing or holding refers to the act of maintaining temporary possession of medicines in the supply chain process, during which no movement of the medicines will occur (13). It

is important for facility to define appropriate storage locations to ensure that adequate controls are in place. Locations include buildings and facilities for medicines storage such as warehouse, storage, or hold area, the original manufacturer's warehouses, contracted warehouses, wholesale distribution warehouses, retail pharmacy storage area, hospital pharmacy storage areas and border Customs storage areas (70). Storage areas are required to maintain the drug temperature between the limits as defined on the medicine label. For example, exposure to high temperatures is likely to be a major contributor to poor performance of mRDT, most manufacturers recommend mRDT storage between 2ºC and 30ºC. Expiry dates are generally set according to these conditions (91). If kits are stored at temperatures exceeding the recommended limits, it is likely that the shelf life of the mRDT will be reduced and sensitivity lost prior to the expiry date, this will lead to a loss and also to place an unnecessary interim order (71). If the temperature is too high, mRDT kits can be refrigerated. Other things which should be avoided in the storage so that to improve the quality of mRDT or NVP syrup is as follows: do not store mRDT kits or medicines near chemicals such as cleaning materials that emit fumes. Reduce humidity by adequate ventilation and repair all leaks. Try not to store supplies directly on the cement floor. Keep the store free of pests (71).

Buildings and facilities used for the warehousing, storage, and/or holding of medicines and mRDT should be of adequate size for their intended use. These facilities should be adequate to prevent overcrowding. Hence the medicines should be ordered by following proper procedures in order to avoid overcrowding. For example, considering maximum and minimum level. Storage should be orderly and should provide for the segregation of approved, quarantined, rejected, returned, or recalled drugs (41,71).

Many health facilities in Oshana and Namibia at large, the storage is still facing a lot of challenges such as limited space, lack of a standby generator, irregular cleanness of the store, shortage or lack of pallets and shelves to keep the medicines away from the floor, lack of trained staffs on the issue of storage of medicines, a unsecure storage area which attracts cats, reptiles, theft and improper documentation because any staff can go in the store and pick medicines without recording (30).

2.6.5 Inventory Management

This process usually involves controlling the transfer in of units in order to prevent the inventory from becoming too high, or dwindling to levels that could put the operation of the health facilities in jeopardy, it is all about knowing what is on hand, where it is in use, and how much finished product results (41).

There are three key aspects of inventory; the first one has to do with time. In terms of materials acquired for inclusion in the total inventory, this means understanding how long it takes for a supplier to process an order and execute a delivery. Inventory management also demands that a solid understanding of how long it will take for those materials to transfer out of the inventory be established. Knowing these two important lead times makes it possible to know when to place an order and how many units must be ordered to keep production running smoothly (62). Calculating what is known as buffer stock is also key to effective inventory management. Essentially, buffer stock is additional units above and beyond the minimum number required to maintain production levels (72,73). Creating buffer stock helps to minimize the chance for production to be interrupted due to a lack of essential parts in the operation supply inventory. Inventory management is not limited to documenting the delivery of raw materials and the movement of those

materials into operational processes. The movement of those materials as they go through the various stages of the operation is also important. Typically known as a goods or work in progress inventory, tracking materials as they are used to create finished goods also helps to identify the need to adjust ordering amounts before the raw materials inventory gets dangerously low or is inflated to an unfavorable level (72).

This often means boosting the production of newly completed goods to the inventory totals as well as subtracting the most recent shipments of finished goods to buyers. When the company has a return policy in place, there is usually a sub-category contained in the finished goods inventory to account for any returned goods that are reclassified as refurbished or second grade quality. Accurately maintaining figures on the finished goods inventory makes it possible to quickly convey information to sales personnel as to what is available and ready for shipment at any given time. In addition to maintaining control of the volume and movement of various inventories, inventory management also makes it possible to prepare accurate records that are used for accessing any taxes due on each inventory type (31).

Tracking inventory is an essential part of the supply chain, there are two common methods, namely Periodic inventory and Continuous inventory reviews, which are used to track inventory for accounting and ordering purposes. Periodic inventory review involves counting and documenting inventory at specified times and it is less time consuming, although difficult to ascertain when reordering items are necessary. Continuous inventory review involves a system that tracks each item and update inventory counts each time an item is removed from inventory. It permits real-time updates of inventory counts, which can make it easier to know when to reorder items to

replenish inventory, but it is very costly because it need bar code scanner, inventory software and computer system (22).

2.6.6 Safety Stock

Safety stock can be thought of as buffer inventory, which is not planned to be consumed, but is held in case of emergency (22,31). Safety stock is especially very important in organization or institution where customer services are the key success factor. It is absorb any internal or external supply and demand shocks to the supply chain. It can also help mask or cover other problems present in the supply chain temporarily. Safety stock can be determined in many ways. Some businesses or operations determine safety stock levels by past history of events, a certain number of days of demand, as a percentage of periodic order sizes, or through a probabilistic model. Whichever the method used, safety stock cannot prevent stock out by 100% (31).

Some institution or organization is depending on gut feeling or some assumptions to set up the safety stock level, which in turn give poor performance of inventory management. A sound mathematical approach to safety stock is not only justify required inventory level, but also balance the conflicting goals of maximizing customer service and minimizing inventory cost (18). The safety stock used to mitigate the demand variability, however, when lead time variability is the primary concern, then the safety stock become standard deviation of a lead time (σ^2L) times the Z score and average demand (avg D), or SS (safety stock) = Z x σ^2L T x Davg. In case both lead time and demand are varies then safety stock can be the sum of the combination of the two. If the lead time and the demand are varies and are independent to each other but there are all normally distributed, which means there are different factors influencing the two, then the

combined safety equation become $SS = Z\sqrt{(\frac{PC}{T} X \delta D^2) + (\delta LT X Davg)^2}$. PC is total lead time and T is time increment.

There are some studies done in the various countries globally, regarding the safety stock level. A study conducted in South Africa on the safety stock adjustment procedure (SSAP), which enables the determination of safety stocks that ensure target service levels in simulation studies of inventory systems. The technique was based on a netting procedure constructed so that the net requirement process and the replenishment process were independent of the safety stock and that the inventory process satisfies an invariance relation. The procedure was presented for three kinds of service measures; namely the cycle service level, the fill rate and the ready rate. In a numerical example the benefits of using the safety stock adjustment procedure are shown. In this example, three wellknown lot size models are compared assuming stochastic and time-varying demand. Moreover, we propose the safety stock adjustment procedure to be used in practical situations to set safety stock levels in companies for instance when demand is non-stationary (74).

Another study was conducted in India on how much the company could lower safety stock levels without affecting customer service. The company chose two of its most popular products as the focus of the study; one which is primarily distributed in North America, and another distributed through a global network. The goal of the project was to find a way to lower inventory levels while maintaining at least a 98 percent service level target. A number of tools were used to study the challenge, including, network optimization to capture in-transit inventory and cycle stock levels in the distribution networks, inventory optimization to calculate how much safety stock to hold and where

to hold it and simulation to validate the results. The findings show that the company currently holds some fixed weeks of inventory depending on lead time for different distribution locations, without the benefit of statistical analysis on demand or lead times, so the potential for improvement was significant. The final analysis exceeded expectations the LLamasoft model showed how the company could reduce inventory levels in one network an average of 6.4 days and the other an average of 7.9 days while improving service levels to 99.5 percent. Overall, the reduction in inventory across both networks was 27 percent, enough to produce a significant impact to the bottom line (45).

The other study in Nigeria, examine the placement of safety stocks in a supply chain for which we have an evolving demand forecast. Under assumptions about the forecasts, the demand process, and the supply chain structure, the show that safety stock placement for such systems is effectively equivalent to the corresponding well-studied problem for systems with stationary demand bounds and base stock policies. Hence, the study uses existing algorithms to find the optimal safety stocks. Use of a case study with real data to demonstrate that there are significant benefits from the inclusion of the forecast process when determining the optimal safety stocks (75).

2.6.7 Distribution

This stage is the act of bringing medicines and mRDT into HF, while transferring refers to the moving of medicines and mRDT internally within a facility or into or out of a vehicle. Inventory and stock management track usage, and then inform the next round of the process, beginning again with medicines and supplies selection based on need (6,23). The required stock levels at all stocking points, for example, the warehouses at the pharmaceutical warehouse and the hospital, should be maintained at all times, taking into

account factors such as lead-times (LT), replenishment cycles and safety stock (SS) (55). There should also be a system in place that easily tracks the location and movement of stock at all points. To achieve this, good communication and information (computer) systems is required. A consistent data structure has to be established throughout the supply chain to facilitate effective and efficient decision-making and execution. Data on factors such as stock quantities on order, lead-times, stock balances in the warehouse, and all other relevant documentation should always be accurate and available for retrieval. The proper management of inventory and warehousing is key to a successful medicines and mRDT distribution system. Warehousing is an essential requirement for not only the storage of inventory, but also to facilitate the proximity of the stock to the customers and the preparation of ordering stock. Furthermore, a warehouse must have a proper schedule of the dates and times to make deliveries; which batch of consignment to deliver and shipment documentation to accompany the consignment being transported when scheduling deliveries (21).

Storage of a drug product includes not only the period during which the drug product is held in the manufacturer's storage areas, but also time spent in the receiving bay area. When medicines and mRDT arrive at warehouse loading docks and other arrival areas, they should be transferred as quickly as possible to a designated storage or within a time period that is consistent with the risk and exposure of the product in the receiving area to a designated storage environment to ensure minimal time outside specified storage conditions as described in a written procedure (56,65).

Relative to the incoming receipt of medicines, it is recognized that the process of medicines and mRDT reaction to ambient conditions begins immediately and may occur

quickly (e.g., reach temperature equilibrium within minutes to a few hours depending on details such as mass, volume, and packaging density taking into account secondary and tertiary packaging). Time spent in a transport vehicle is considered to be part of the distribution process and is not a storage location. Deliveries should be examined on receipt in order to check that containers are not damaged and that the consignment corresponds to the order (65). The results of this examination should be documented.

Appropriate delivery records (e.g.,As applicable, transport vehicle movement papers, receiving/delivery records, data logging records, temperature recorders and similar devices, bill of lading, house air way-bill, master air way-bill) should be reviewed by each receiving entity in the supply chain to determine if the product has been subjected to any transportation delays or other events that could have exposed the product to undesirable conditions.

Distribution of medicines and mRDT occur within a facility or location, such as a manufacturer, wholesaler, pharmacy dispensing area and clinic/hospital. Distribution occurs as point-to-point movement within the supply chain between distribution facilities via semitrailer trucks, vans, emergency medical service vehicles, industry representatives' automobiles, trains, aircraft, sea vessels, and mail delivery vehicles (71).

Communication within the supply chain should be coordinated to determine the proper timing for drug products to be transported and received, taking into account holiday schedules, weekends, or other forms of interruption. When international distribution is required, alerts should be made in advance and proper language should be used to ensure understanding of the requirements set forth in drug product labeling.

2.6.8 Lead Time

Lead time is the time which including process of preparing material, produce and transport to customers. So how long of lead time depend on type of material, product and process. The mean delivery time is a part of the lead time,which involves only the transport period to the customer (65,71).

There are studies conducted in different organizations regarding the impact of lead time in the service delivery,which examine several stochastic demand processes where order lead times are constant. In reality, lead time is rarely constant; unpredictable events in the supply system cause unpredictable delays. It is true that in certain special cases, lead time uncertainty has essentially no effect and can be ignored (56). Nevertheless, more often, lead time fluctuations strongly degrade performance, just as demand uncertainty does. Seemingly, lead time uncertainty has been neglected for a long time in favor of studying demand uncertainties. Industry agrees that it is overdue and there is a need to rectify this oversight. Nowadays, this gap in research activity begins to be filled in order to respond to companies having non-deterministic lead-times constraints. (71).

The study in Egypt was conducted regarding the focus on the implications of providing faster service to top tier customers. A simulation model was developed using arena simulation software to model an order fulfillment process in which top tier customers always receive priority over the middle and bottom tier customers, and likewise middle tier customers over bottom tier customers. Through scenario analysis, the researcher studied the effects of different system variables at the time in the system for each tier, namely different proportions of customers or orders in each tier, different process variability, and different utilization levels of the system. The results show that between

the ranges of orders for top tier: 1-20%, middle tier: 20-40% and bottom tier: 55-70%, there are similar results on lead time. Top and middle tier customers always have an average and maximum lead time less than that of the benchmark case in a first-in first-out system. On the other hand, bottom tier customers always take longer than in the benchmark case. With a wider range of proportions for each tier, the top tier reaching as high as 60%, this is true as well. However, the time in system for bottom tier customers or orders grows exponentially as the proportion of top tier customers or orders increase. In terms of process variability, the results show that variability has a minimal effect on the average time in the system for all tiers of customers. However, as the variability of the system increases, the maximum time in system for bottom tier customers is highly volatile, thereby making it difficult for managers to set customer expectations of lead time. The utilization level affects the bottom tier customers the most, whereby the relationship between utilization level and maximum time in system for bottom tier customers is exponential. Through this study, it was recommended that managers can use this data to aid in priority management and set reasonable customer expectations of lead time (56,65).

2.6.9 Consumption of Medicines

In Low Middles Income Countries (LMIC) , the pattern of consumption of essential medicines is not well documented compared to the high income countries, but some studies show that high income countries are consuming a lot of essential medicines with branded names (originator) compare to Low and Middle income countries (76).

The consumption data can be measured using the adjusted consumption method to estimates medicines requirements on the basis of actual medicines use per 1,000 patient

contacts in a health facility, where the pattern and level of consumption are considered acceptable. In some cases an adjustment upwards or downwards may be needed for drug quantities where consumption is considered inappropriate. Acceptability is when the prescribing pattern is widely reasonable and the pattern of morbidity treated is representative of the pattern in the rest of the region concerned (76,77)

Prescribing pattern compared with the morbidity method, offers less scope for systematic development to improve supply chain of essential medicines and prescribing practice. Its advantages are that it does not require either detailed data on patient morbidity, or standard treatment schedules. However, users of this method should pay particular attention to the fact that some irrational consumption patterns in the health facilities, which are not corrected in the adjustment process, will be included in the medicines estimates for all facilities of the type covered by the calculation (77).

From two methods above, it shows that consumption of medicines is not always the same as the need of medicines; this can be due to indiscriminate prescribing or the use of expensive form of medicines whereas simpler and cheaper preparation would be suffice. In addition, for the adjusted consumption method to be successful, it is crucial to improve prescribing in order to bring it into line with the medicines need estimates, in order to achieve this the use of standard treatment guidelines should be emphasized (76).

2.6.10 Policy of Supply Chain Management

National Quality Assurance Policy for Medicines and Other Health Products as assures that consumers have access to medicines and other health products that meet the accepted standards of quality, safety, and efficacy. In any supply chain management cycle the

policy, quality assurance, monitoring and evaluation is very important to make sure that all stages in the cycle are properly monitored and evaluated (18).

Pharmaceuticals involve many parties, including patients, doctors, other health workers, drug sellers, and manufacturers. The complexity of managing pharmaceuticals, the large number of interested stakeholders involved, and the value of the products make pharmaceutical systems vulnerable. The field also involves important risks people can die not only from a lack of medicines, but also from medicines that are substandard or fake, wrongly prescribed, or used incorrectly. The consequences of using inferior pharmaceutical products can prolong the required therapy period, exacerbate the illness, and may cause resistance to antimicrobials. it also undermines patients' confidence in the health care system. It is easy, therefore, to see why laws and regulations are needed (34). Through the establishment of pharmaceutical laws and regulations, countries can set quality standards and pricing guidelines, require licensing of dispensers and outlets, and establish production guidelines. Medicine registration is often a major element in the legislation to ensure that individual products meet the criteria of efficacy, safety, and quality. Medicine policy guides budget allocations, research and development priorities, and education initiatives and defines the role of the public and private sectors in pharmaceutical manufacturing and distribution (69).

A country usually has a regulatory authority that oversees laws and regulations; however, many countries do not have sufficient regulatory infrastructure or resources to effectively monitor the quality, safety, and use of pharmaceutical products. Lack of quality assurance can result in the wide availability of substandard and counterfeit products. In addition to

patients increased access to essential medicines comes a greater need to monitor and promote medicine safety and effectiveness called Pharmacovigilance (63,69).

2.6.11 Namibia National Drug Policy

The National Drug Policy for Namibia address all main areas or components which impact pharmaceutical sectors such as legislation and regulation, drug procurement and distribution, the appropriate use of drugs by health workers and consumers, human resources development, drug pricing, financing and quality assurance measures, with the ultimate goal to meet the requirement of Namibian people in the prevention, diagnosis, and treatment of prevailing diseases, using efficacious, high quality, safe and cost-effective medicines.

2.7 Health Programs

Due to the burden of malaria and HIV/AIDS There are two international health program focus on the following.

2.7.1 Prevention of Mother to Child Transmission (PMTCT) program in Namibia

Human Immunodeficiency Virus (HIV) can be transmitted from an HIV-positive woman to her child during pregnancy, childbirth and breastfeeding. Mother-to-child transmission (MTCT), which is also referred to as 'vertical transmission', accounts for the vast majority of new infections in children (78)**.** In order to prevent MTCT, the World health organization (WHO) came up with PMTCT programs which provide a package of services, among the services offered is the provision of prophylactic Nevirapine (NVP) syrup to a child who born to an HIV positive mother (78-85).

The Namibia Ministry of Health and Social Services (MOHSS) firstly introduced PMTCT services at the Katutura state hospital in Khomas region and Oshakati State hospitals in Oshana region in 2004 and later on, the service was disseminated countrywide, including all 35 States and Church hospitals and to 153 health facilities and clinics in the public sector (86). Generally in Namibia, the PMTCT implementation coverage is 90% coverage of all health facilities, with 95% infant NVP syrup prophylaxis coverage (86).

2.7.2 Availability of Nevirapine Syrup for PMTCT

Nevirapine medicine, which branded as Nevimune is abbreviated as NVP. It can be in tablet formulation or syrup formulation. This medicine is used with other HIV medications to help control HIV infection. NVP is not a cure for HIV infections; rather it helps to decrease the amount of HIV in the body so the immune system can work better. This lowers a chance of getting HIV complications (such as new infections, cancer) and improves your quality of life**.** Nevirapine belongs to a class of drugs known as non-nucleoside reverse transcriptase inhibitors (NNRTIs) (21).

This medicine is used mostly in elimination of mother to child transmission (eMTCT) or prevention of mother to child transmission (PMTCT) program. NVP syrup prophylaxis is given to the infants who are highly at risk (15). The medicine is given to the newly baby born until at the age of 6 weeks or beyond. The dose depends on the weight of the baby. In most cases NVP syrup can be in the bottle of 100ml or 240ml at the concentration of 10mg/ml. In this study the volume of NVP syrup is 240ml because it is the most parked volume that are ordered compares to 100ml.

Though there are a lot of success stories about PMTCT program, there are some challenges regarding the provision of NVP syrup in health facilities which has been reported (87). Some health centers and clinics reported inadequate space, especially for storage of NVP syrup. Some PMTCT mothers and infants received follow-up services at facilities where they are not registered (visitors) and could be regarded as lost to follow-up where they are registered and yet there are not, lack of proper documentation. These challenges have hindered estimation of consumption of NVP syrup. The other challenges are stock out and expired (87).

The study conducted in Eastern Uganda aimed at listening to health workers and gaining lessons for strengthening the program for the prevention of mother to child transmission of HIV. They noticed that there was no consistency of NVP syrup supply to the facilities and hence another challenge for running the PMTCT program had cropped up. As a consequence, some of the study sites reported running out of test kits and nevirapine for mothers and babies. Other sites even decided to refer the needy mothers to the larger centers and hospitals where drugs were more readily available. Generally the whole process of going to one clinic and then being referred to another large center or hospital became very costly for women and their families (88).

Since nevirapine syrup is largely needed for PMTCT programs, the record keeping and reporting at the health facility is largely done by incharge or the supervisor of the health facility (81).

In Oshana region the supply chain of NVP syrup differs from facility to facility depends on the availability of staffs and internal arrangement of the particular health facility. For

some health facilities, a pharmacist or pharmacist assistant orders NVP syrup from OMRMD, record on the stock card and stock in the pharmacy store of the health facility. Pharmacist or pharmacist assistant issue NVP syrup to antenatal care (ANC). Consumption of NVP syrup will be recorded in the nevirapine register in terms of volume consumed for each baby. For other health facilities, nurse in charge orders NVP syrup from OMRMD and directly record amount received in the nevirapine register book, and store in the cupboard in ANC room and issued according to the demand. In every health facility, in charge or supervisor compiles the report of consumption of NVP syrup and send to primary health care (PHC) supervisor or principal medical officer (PMO) at the district.

2.7.3 National Malaria Control Program in Namibia

National Vector-borne Diseases Control Program (NVDCP) in Namibia has successfully made malaria diagnosis and treatment available for free to both citizens and foreigners in all health facilities whereby, the Directorate of Special Program (DSP) is a directorate of the Ministry of Health and Social Services (MoHSS) that oversees all activities related to HIV/AIDS, tuberculosis, and vector-borne diseases, including malaria (89).

Figure 5, depicts the organizational structure of the NVDCP which is part of the DSP. At the regional level, malaria services are managed by the Environmental Health Unit and DSP focal persons. At the district level, malaria activities (i.e. Diagnosis and treatment, and community outreach) are executed by the Primary Health Care supervisors and Environmental Health Officers (EHOs). At health centers and clinics, nurses provide case management services to the higher levels. That is a request for training, transport and weekly malaria report.

In some areas, non-governmental organizations (NGOs) help conduct information, education and communication (IEC) campaigns. The Central Medical Store (CMS) provides all medicines and clinical supplies required to carry out malaria case management (89,90).

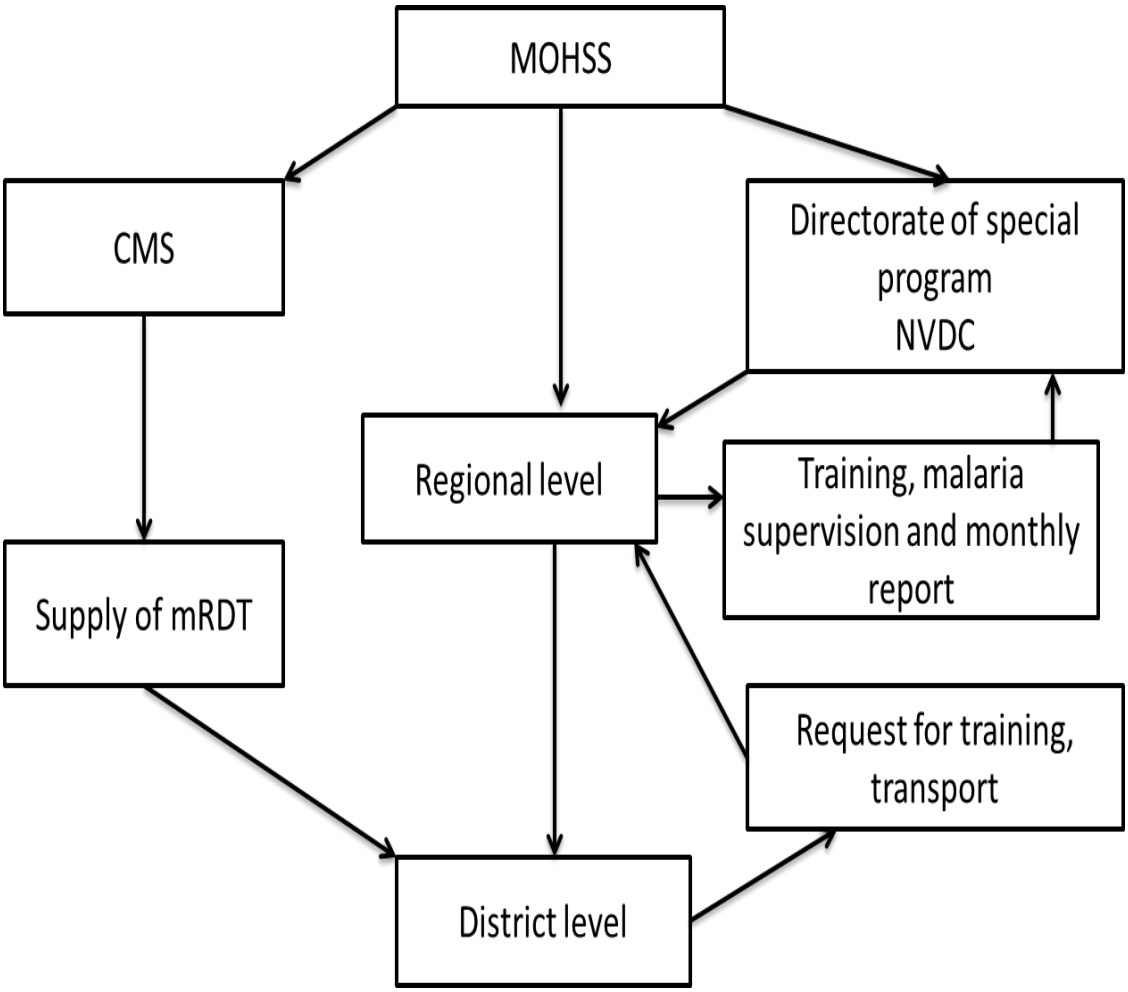


Figure 2. Shows the supply chain of mRDT from CMS to the lower levels and flow of information from the national level/directorate of special program to lower level and vice versa as adapted and modified from a case study of malaria strategies and costs along the northern border (90).

2.7.4 Malaria Rapid Diagnostic Test Kit (mRDT)

At the beginning of 2005, national guidelines called for clinical diagnosis with parasite confirmation using microscopy or a Malaria Rapid Diagnostic Test (mRDT). The mRDT is an immunochromatographic test that detects specific antigens produced by malaria parasites that are present in the blood of an infected individual (90). The mRDT used in

Namibia aids in the diagnosis of malaria infections by rapidly detecting all four species of malaria. This kit is very useful in the resource limit settings (89). The mRDT were procured by Global fund for AIDS, Tuberculosis and Malaria (GFATM) and distributed for the first time in 2005, and were available in 90% of district health facilities by 2006. In 2011, a new RDT with improved sensitivity and specificity to *Pf* and the ability to test for multiple parasite species was procured (figure 5).

2.7.5 The Use and Availability of mRDT

The marked increase in the use of mRDT is a result of policy changes that emphasize the need for testing to guide therapy, expansion of testing and treatment programs that are part of the global effort to control malaria, and availability of funding to make these tests available. According to the national malaria case management guideline (90), all fevers and suspected cases must be tested with mRDT and in order to ensure its efficacy, the mRDT must be maintained between 1°C to 30 °C (90). Use of mRDT has resulted the reduction of artemisinin combination therapy (ACT). The study conducted in Ghana showed that when mRDT were introduced; in areas that previously did not have microscopy, introduction of mRDT was associated with a significant reduction in the use of antimalarial drugs/ACT (91).

Another study conducted in healthcare settings in Dar es Salaam, showed that the use of mRDT was associated with significant decreases both in the number of patients classified as having malaria and in the number of patients with a negative test result who were treated with antimalarial (91). One box of mRDT can test 20-25 patients, but in this study mRDT is marketed as a kit containing 25 tests or pack of 25 tests in each box (92).

In Namibia, NVDCP introduced a weekly surveillance system in which district DSP focal persons compiled surveillance forms with additional key indicators (e.g. Number of fevers tested, patient age, local or non-local case origination). Even though these data flow from districts to regional and national levels, they are not analyzed and information that could facilitate intervention targeting does not flow back down to district programs (93).

The stock out of mRDT was one of the challenges of availability of diagnostic test which attributed to a lack of inventory monitoring and proper forecasting. Lack of training on proper use of mRDT, training, IEC and community outreach to increase awareness and knowledge was reported as the challenges which cause stock out and increase expired of mRDT (93).

2.8 Inventory Models of Stock Levels

Inventory model is a mathematical model that helps business in determining the optimum level of inventories that should be maintained in a production process, managing the frequency of ordering, deciding on quantity of medicines or goods to be stored, tracking the flow of supply of raw materials and goods to provide uninterrupted service to customers without any delay in delivery (94). On that point are mainly two inventory models in supply chain, namely deterministic and stochastic inventory models. Basically deterministic models built on the assumption that there is no uncertainty associated with demand and replenishment of inventories, while the stochastic inventory model take assumption that there is always some degree of uncertainty associated with the demand pattern and the lead time of the inventories (94,95). These models play an important part in defining the optimal ordering and pricing policies (95). Much study has been described

in literature regarding inventory models with finite and infinite replenishment, but in many practical situations the replenishment is governed by random factors like procurement, transportation, environmental conditions and accessibility of sensitive fabrics. Hence there is a need to develop inventory models with random replenishment. It is very important for institution such as health facility to recognize what the optimal inventory level must be, in order to answer the demand of the customers (95).

The following are studies done in different countries on the optimization of inventory models with the aim of improving supply chain system.(41,96) .

The study performed in India on inventory model for deterioration of items with Weilbull replenishment and generalized Pareto decay, having demand as a function of on hand. In this study the inventory was conducted in which EPQ model for deteriorating items was developed and analyzed with the premise that the replenishment is random and follow Weilbull distribution. The study assumed that the life time of the item is random and follow the a generalized Pareto distribution and demand is a function of on hand inventory. Using a differential equation the instantaneous state of inventory is derived. Through numerical illustration the sensitivity analysis was carried out. The sensitivity analysis of the model reveals that the random replenishment has significant influence on the ordering and pricing policies of the model. The study includes some of the earlier models as particular cases for specific values of the parameters (96-99).

Another study was done was conducted in USA on classical inventory models with the aim to address this issue using empirical information. The study examines the absolute and relative inventories using a quarterly data panel that contains 722 public USA

institutions for the period of 1992-2002. All the institutions were largely relied on inventory management in order to focus on empirical testing hypothesis derived from a mixture of a classic inventory model (Economic order quantity, new vendor, periodic review etc). The study found that the empirical evidence that institutions operating with more uncertainty demand, the long lead time and higher gross margins have higher inventory levels. Furthermore, large institution appears to benefit from economies scale and thus call for relatively less inventory than smaller establishments. The study obtained mixed evidence on the relationship between stock levels and stock keeping costs. The overall results demonstrate many of the predictions from classical inventory models extend beyond individual product to the more aggregate institution level, so these models can help with high level strategic choices in addition to the tactical decisions (100).

In Ukraine the study on literature review on models of the inventory management under uncertainty was conducted, using the fuzzy model. The model was chosen due to the fact that the values of some factors are very difficult to define or almost unreal, but a fuzzy model of inventory management takes an important place. The study analyzes possible parameters of existing models of inventory control. An attempt was made to provide an up to date review of existing literatures concentrating on a description of the characteristics and type of inventory control models that have been developed (99,100).

In Victoria, Australia the study was conducted on the inventory control with gamma probability distribution. This study indicates that the gamma probability distribution encompasses both normal and negative exponential probability distribution models to represent the lead time demand of fast and slow moving items respectively, as a special case but also covers the gap left by them. As the knowledge about the problem has

increased there has been a general tendency towards greater simplification. This study continues the trend by introducing an approach that depends only on concept from basic statistics. The objective is to obtain rid of unnecessary complexity and prepare the associated theory easier to understand (101).

The similar study was conducted in Italy on an inventory model based on order quantity and lead time as decision variables. Demand frequency and quantities corresponding Poisson and normal distribution show that a different viewpoint was proposed in comparison with the unit time demand. Hypothesis of lead time and ordering quantities based on an inventory model that reorder point is proposed by Ben-Daya and Raouf. In this study the proposition was to apply the negative exponential function for crash cost and then to build an inventory model based on ordering quantities and lead time under the hypothesis of demand frequency and quantity corresponding Poisson and normal distribution (41).

A study done in North Carolina in USA on a solution to the (Q, r) inventory model for gamma lead time demand show that an institution that ignores the lead time demand variability may suffer great financial damage, that the gamma distribution provides the most common best fit to lead time demand for a variety of inventory items, and that of a fixed lead time demand assumption is usually very much skewed to the right. Unfortunately, all of the methods for solving the (Q, r) inventory model with gamma lead time demand and call for tabulated values and perhaps and converges to the optimal solution quadratically. The solution for two special cases of gamma lead time demand were also discussed (101).

The similar study done in Egypt on the application of modified generalized gamma distribution in inventory control, with the aim of determining of the protection lost sales (i.e., the probability of not going out of stock) and the potential lost sales i.e., unsatisfied demand) when the lead time demand has a modified generalized gamma distribution. By using the maximum likelihood method in this study, the five parameters of the modified generalized gamma distribution were calculated. The protection and compliment of the protection lost sales, the mean and variance of the potential lost sales for the modified generalized gamma distribution and its special cases were estimated. The study concluded that the optimal reorder point can be achieved when protection lost sales are equal to one, and consequently the complement of protection lost sales are equal to zero. Therefore, there are no orders which are not met, where the mean of the potential lost sales is equal to zero. The other conclusion was that the more the number of model parameters as the results are better. It was observed that in this study the models contain generalized gamma function are better than the model that contain ordinary gamma function (97).

Another study done in East Asia on the choice of a demand distribution for inventory management models shows that the Poisson probability distribution has been found to provide a reasonable fit when the demand is very low. However the functional form of the probability distribution is often incomplete in practice. For instance, it might be that only the first moments of the probability distribution are known. This incomplete information is a problem as the shape of the distribution is important in terms of performance of inventory control. The procedure was described to determine shape

characteristics when only the first two moments of distribution of demand during the lead time are known, using a compound Poisson distribution and the Pearson chart (102).

The study done in Nigeria considers the problem of safety stock levels for the production of multiple items, each with random demand across multiple facilities. The traditional methodology for calculating safety stock was discussed and on the alternative method for improving service level was presented. Normal and gamma probability distribution were studied to estimate safety stock levels and the performance of both models along with hybrid approach were tested in a large scale case study example. The results of this case study indicate that a better inventory policy with less underage cost, can be achieved by using a proposed models and solution procedures (103).

The other study done in Ivory Coast on inventory management with log-normal demand per unit time, examined optimal policies in a continuous review inventory management system when the demand in each time period follows a log normal distribution. In this scenario the distribution of demand during the total lead time period has no known form. The proposed procedure uses the Fentton- Wilkson method estimate. The parameters for a single log normal distribution that approximates the probability density function that approximate the lead time demand distribution **(**21).

2.9 Summary

This chapter provided details of the conceptual framework on how different variables can lead to stock out of medicines and global health supply chain, supply chain in Africa and supply chain in Namibia and Oshana region, current practices and other development of health supply chain. Supply chain in Namibia was detailed explained; this was accompanied by an overview of the supply chain management cycle. International, national policies, laws and other decision making that influenced and have an impact on supply chain and promote quality health services were also discussed. The research methodology for analyzing stock level model in Oshana was discussed in the following chapter.

CHAPTER 3: MATERIALS AND METHODS

3.1 Study Design

The investigation at this stage concentrated on bottlenecks, inaccurate consumption information, cost drivers and detailed examination of the supply chain for the essential medicine, NVP syrup, and malaria rapid diagnostic test (mRDT), all of which might cause stock-outs. The study captured examples and opinions from informants in Oshana region. In response to demand for diverse sources of evidence, a mixed-method design was adopted to produce a wider view of the overall subject, supply of mRDT and HIV/AIDS medicine, NVP syrup in particular. The design involved the concurrent triangulation-convergence model, starting with collection of quantitative data followed by qualitative data. The researcher produced a convergence between the two sets of data, typically by bringing separate results together for comparison and interpreted the results.(figure 6). Though triangulation is the most reliable method for this study, challenges appeared, which included totally mismatched data. To resolve contradictions, the researcher collected additional data whenever the problem arose.

In order to achieve the following objectives, examine the consumption rates and trends of mRDT and NVP syrup in Oshana region, factors associated stock out of mRDT and NVP syrup, develop a mathematical model of stock level for mRDT and NVP syrup in the healthcare system ,perform a simulation of the secondary parameters using a validated model to assess and evaluate its efficiency. A retrospective, quantitative, descriptive design was appraised over a five-year period. Adherence to this design ensured that the acquired data could be quantitatively evaluated and compared, to predict the variance of one or more variables based on the variance of a third variable, and therefore measured,

so that quantitative postulations could be made. Furthermore, a descriptive approach was adopted so that accumulated quantitative data extracted from SYSPRO, Electronic Dispensing Tool (EDT) could be studied in a systematic way by means of tables and graphs. In consideration of time constraints, and for the calibration of data acquisition, operation, a retrospective design was adopted. Thus, data were acquired through records over a specified period of time, 2012 to 2016.

For more insight on achieving the factors associated with stock out of nevirapine syrup and mRDT, a phenomenological design was used to expand quantitative results by interviewing 17 informants in the supply chain of NVP syrup and mRDT. Seventeen informants were from three departments or units, namely, pharmacy, transport and nursing. These departments are located in health centers, clinics and medical store. The informants were interviewed in order to identify factors which are associated with stock out of mRDT and NVP syrup in the region.

Figure 6 is the figurative form of the two methods and how these two methods combined and integrated.

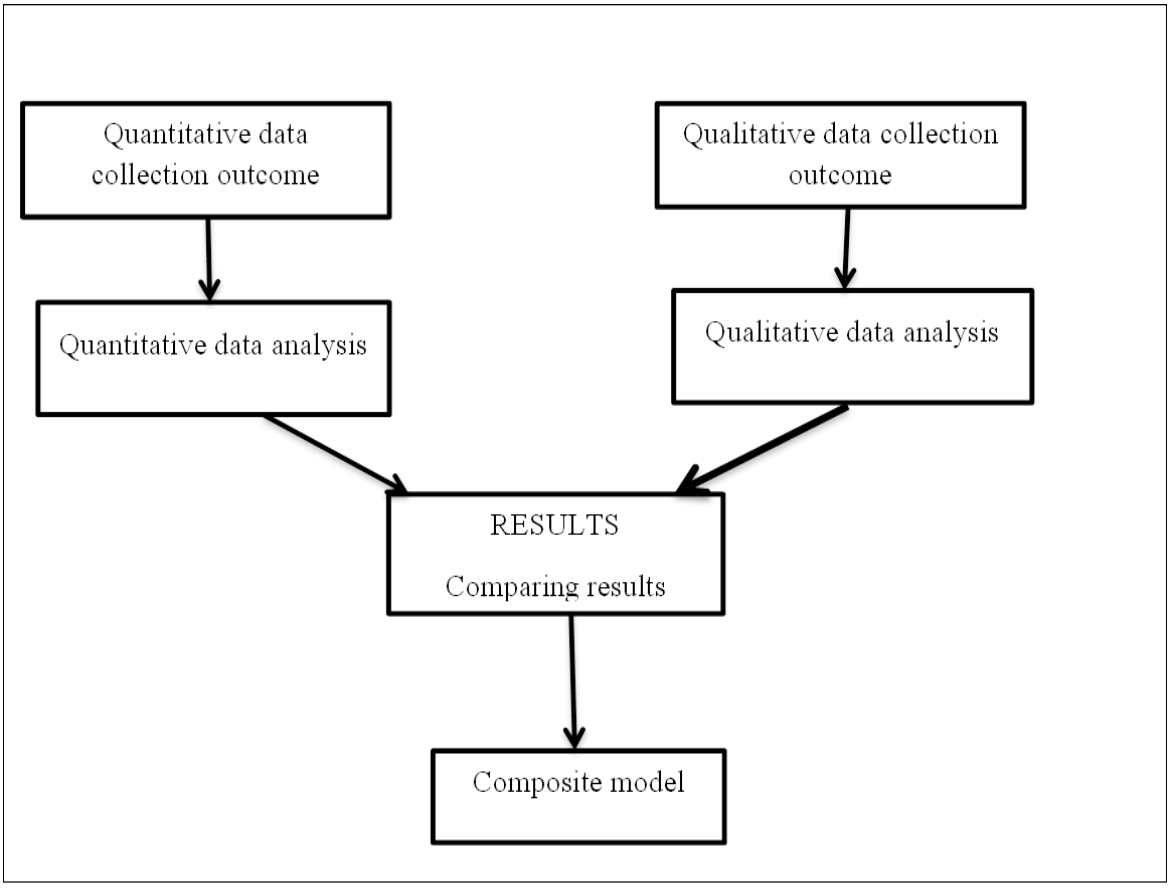


Figure 6. Concurrent triangulation visual model design adapted and modified from mixed methods research course (104).

3.2 Study Population

For the purposes of this study, 'target population' was divided into two groups as follows.

3.2.1 Target Population for Health Facilities in Oshana Region

The Oshana Multi Regional Medical Depot (OMRMD) provides essential medicines and diagnostic test kits for Oshana region's population through its health facilities, centers and clinics. All health centers and clinics in Oshana region providing care for cases of uncomplicated malaria and PMTCT have been in operation since 2012. The health centers are Ongwediva H/C, Ondangwa H/C, Ounick H/C, Okatana H/C and Oshakati

H/C. The clinics are Onamutayi, Eluwa, Enkono, Okaku, Ompundja, Uukwiyuushona, Ekamba, Eheke, Ehafo, Okauukamasheshe and Okaukejo.

3.2.2 Target Population for Informants

The population of Oshana region as a whole is the target for regional healthcare services and its 'informants'. Healthcare workers and those who are not healthcare professionals, who are, nonetheless, involved in some way in the supply chain of essential medicines and diagnostic test kits are referred to as informants. This group of workers includes pharmacists, pharmacist assistants, nurses, transport officers and drivers.

3.3 Study Area

The study was conducted in Oshana region, one of fourteen in Namibia. The researcher chose the region for two reasons. Firstly, HIV/AIDS and malaria are still a public-health concern in the region, most affected group are pregnant mothers and children. However, there is a decline in HIV prevalence rate from 6% in 2015 to 4% in 2016; also the number of malaria cases has declined in the region as only four cases were recorded in 2016 (73). Secondly, the Intermediate Hospital Oshakati (IHO), the only primary referral hospital in northern Namibia, is in Oshana region. With a catchment population of 60% of the country's people, Oshana region holds a large number of items that are under study. Additionally, the Oshakati regional medical depot (ORMD), which serves the entire northern area of Namibia, is located in the region. The ORMD is the source for the supply chain of essential diagnostic test and medicines of HIV/AIDS and malaria in the region (73).

The name, Oshana, is a reference to the name of the region's most prominent topographic feature, namely the shallow, seasonally inundated depressions which underpin the local agro-ecological system. Oshana region is situated in the center of northwest Namibia and shares borders with Oshikoto to the east, Omusati to the south and west, and Ohangwena to the north. Oshana region is the seat of three towns, Oshakati, Ongwediva and Ondangwa, which are governed by municipal councils. There are eleven constituencies in the region, namely Okatana, Ongwediva, Oshakati west, Oshakati east, Okatayali, Uuuvudhiya, Uukwiyu, Okaku, and Ondangwa urban and rural.

Oshana region is the smallest region in the country, 8,647 square kilometers, home to a population of 187,797 people. The majority of the population, 55%, lives in rural areas (Demographic Health Survey (DHS), 2013). Population growth in the region is influenced by pull factors such as growing business opportunities and health services. About 80% of the population enjoys access to health facilities due to reliable transport. On the other hand, 20% of the population experiencing difficulties reaching a health facility due to remoteness or to impassable roads, caused by flooding during the rainy season. Each constituency in the region has several public-health facilities. Some of these constituencies only have clinics and some have a clinic and a health center. Distribution of these health facilities depends on the population distribution in each particular constituency. A population under 9000 will only merit a constituency to have a clinic built, while above 9000 will qualify one to have a health center (74).

The region is home to five health centers (H/C), namely Ondangwa H/C, Ongwediva H/C, Ounick H/C, Oshakati H/C, which is within the Intermediate Hospital Oshakati (IHO), and Okatana H/C which is partly owned by Catholic Health Services (CHS).

There is also a primary health service offered at the correctional facility known as Oluno prison located at Ondangwa town. It is the only facility that caters for Omusati, Ohangwena, Oshikoto and Oshana regions. Oluno prison is the only facility providing primary health care services to inmates and Oluno prison staff under the Ministry of Safety and Security.

The lowest level of health care is offered at the clinics. Oshana region has twelve clinics, namely Onamutayi, Eluwa, Enkono, Okaku, Ompundja, Uukwiyuuushona, Ekamba, Eheke, Ehafo, Okaukamasheshe, Eloolo and Okaukejo. The operation of health centers and clinics is under the direct supervision of registered nurses.

The public-health system in the region has been classified as a single health district in Oshana region, meaning that district health care services have been integrated into regional healthcare services. At the present time, there is no district hospital serving the region, though the regional government has secured land to build a district hospital in Ondangwa town. ART services are distributed between IHO and Oshakati health center. For example, PMTCT services are offered by Oshakati health center, which is part of the IHO. The remaining ART services are offered by the IHO. Intermediate Hospital Oshakati is a referral hospital providing tertiary care, clinical education and training for future and current health professionals. Primary health centers provide primary health care services to populations exceeding 6000. Clinics provide health services to populations under 6000.

Oshana region, like other regions in the country, provides various health services in collaboration with international and local non-governmental organisations (NGOs), including those organisations which target specific public-health concerns, such as

HIV/AIDS, malaria and tuberculosis. Health services to fight HIV/AIDS, malaria and TB in Oshana region are supported by the center for Disease control (CDC), Potential Namibia and Global fund. In the region there is an HIV mentor, a malaria clinical mentor, an HIV-nurse mentor and other ART and malaria staffs who are working in collaboration with the chief administrator of the special programme under the MOHSS. These mentors make sure that HIV and malaria intervention activities in the region are progressing in a satisfactory manner and that targets are being met.

All health facilities in the Oshana region are either completely or partially drawing their supplies of medicine from the Oshakati multi-regional medical depot which is located in Oshakati town.

Apart from primary health centers and clinics situated in Oshana, there are also 46 outreach sites or outreach points that provide services to the communities. All the services provided by these outreach points are organised and supervised by Oshakati Primary Health Care. Of those sites, 10 are now integrated with the ARV services, commonly known as community-based ART (CBART) service centers. These 10 outreach points have the necessary infrastructure (electricity, water and protected environment) to host ART services. The outreach-site initiative helps bring services closer to communities, specifically those communities prone to flooding and those at a great distance from the health facilities, and will help the region achieve the 90-90-90 goals (76).

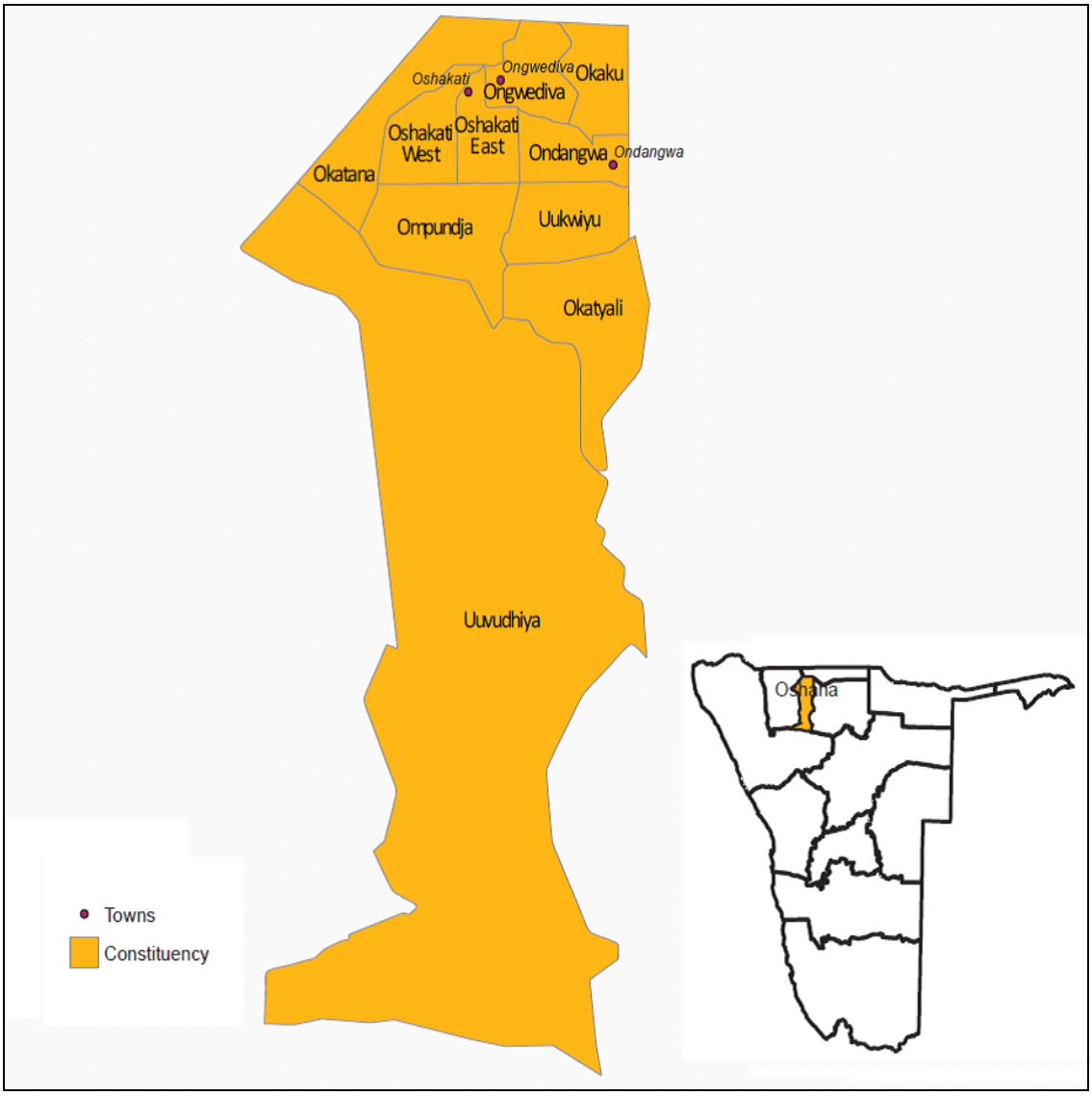


Figure 7. Map of the Oshana region (Yellow colored) shows the constituencies where public health facilities are located and regions bordered with Oshana region as adopted from Oshana region council (75).

3.4 SAMPLE SIZE

3.4.1 Sample Size for Health Facilities

Relative to quantitative evaluations in the study, sample sizes at the study sites were not considered, since the study dealt with time varied during the years 2012 to 2016 inclusive. The study is about time variables because it is the amount of time that passes between each step in the supply chain, namely order placement, receipt, issuance and consumption that are measured. These increments of time are then tabulated, or plotted, as chronologically organised data points in the ordering sequence, namely weekly, monthly or annually. In order to yield valid statistical inferences, these increments of time were measured repeatedly over a five-year period. The quantities of EM received and consumed, as well as the storing costs, transportation costs, expiry costs and cost of expired medicines, was then further analysed relative to four time-period variations, which are secular trend, seasonal variation, cyclical variation and irregular variation.

Eloolo clinic was eliminated from the study because its period of operation did not extend over the entire period under investigation, namely 2012 to 2016, i.e. the clinic has no documentation prior to 2015. The study sites were Oshakati Multi-Regional Medical Depot (OMRMD), IHO, Ongwediva HC, Okatana HC, Ounick HC, OndangwaHC and Oshakati HC. Primary health clinics were Onamutayi, Eluwa, Enkono, Okaku, Ompundja, Uukwiyuushona, Ekamba, Eheke, Ehafo, Okauukamasheshe and Okaukejo.

3.4.2 Sample Size for Informants

The office of the chief pharmacist in Oshana region provided a list of key informants in the pharmaceutical supply chain in the region. However, the researcher stopped recruiting

informants when it became clear that significant or unique themes would cease to emerge from the data and when enough data had been gathered on which a reasonable explanation of the findings could be built. At saturation point the informants were 17.

3.5 Sampling Procedures

3.5.1 Sampling Procedures for Health Facilities

All health facilities in Oshana region were selected for sampling except Eloolo, which is a new clinic, officially opened in 2015. Intermediate Hospital Oshakati was also excluded from the sample because it receives essential medicines (EM) and diagnostic test kits from the Central Medical Store (CMS). Though it should be noted that, in some cases (emergencies, delays and CMS out-of-stock), Intermediate Hospital Oshakati may source EM and diagnostic test kits from OMRMD.

3.5.2 Sampling Procedures for Informants

The researcher used a stratified, purposive-sampling technique to identify health professionals and other professionals based on the size and nature of the environment in which they operate, i.e. whether they work in clinics, health centers, a hospital or in offices at regional-management level, who were key informants in the supply chain of essential medicines and diagnostic test kits in Oshana region. Because of variation in experience and the kind of positions held, the researcher decided to use a purposive sampling technique known as maximum-variation sampling in order to tap the widest possible range of perspectives relating to the supply chain.

3.6 Research Instruments

This study organised research instruments into two categories

3.6.1 Research Instruments used by Health Facilities

Eleven tools were used to prepare documentation for the review process conducted over the five-year period under investigation, 2012-2016 inclusive. These tools were: 1) electronic dispensing tools (EDT), 2) electronic stock cards (FESC), 3) Syspro software, 4) baby-mother-follow-up reports, 5) stock cards, 6) invoices, 7) malaria weekly data, 8) delivery notes,.9) District Health Information System 2 (DHIS2), 10) Namibia health sentinel survey(NHSS) and 11) Monthly economic reports.

Software used to dispense NVP syrup is commonly known as an electronic dispensing tool (EDT). An EDT is used to extract information on the quantity of NVP syrup received from OMRMD, or other health facility, and the quantity consumed by patients. These two variables were important because they measure a health facility's perceived requirement against actual consumption. EDT is also used to identify periods when NVP syrup is out of stock. This variable is important because it indicates periods of time during which the demand for ARVs is not met. Other parameters identifiable with EDT are the maximum- and minimum-levels of ARVs the facility is able to stock or actually stocks. EDT was useful in this study because it helped examine the distribution and utilisation of NVP syrup at health centers and clinics. The use of EDT to extract NVP syrup information was complemented by NVP-syrup registers which are used in cases of prevention of mother-to-child transmission (PMTCT).

Facility electronic stock card (FESC) was used to extract information regarding quantities of NVP syrup and mRDT ordered and received from OMRMD, as opposed to Central Medical Store (CMS). These statistics are important as they indicate the need for NVP syrup and mRDT at IHO, in cases when a main order from CMS has been delayed or when there is a shortage of items indicated at IHO, when the item is available at OMRMD. Also indicated is the quantity of NVP syrup and mRDT issued to various area or points within the jurisdiction of the Intermediate Hospital Oshakati (IHO).

The Syspro software application is used at Oshakati Multi Regional Medical Depot (OMRMD) to manage inventory by identifying the quantity of medicines ordered by OMRMD, the quantity received from CMS and the quantity issued to various health facilities in the region. These variables are important as they indicate the demand and stock requirements for medicines stored at OMRMD. These are equivalent to the demand and the need for essential medicines in the region. Quantities of medicines that expired at OMRMD could also be identified using Syspro software. This variable enabled the researcher to calculate loss of medicines per unit price. This research instrument was utilised to examine selection, procurement and distribution of NVP syrup and mRDT at OMRMD and also to determine cost drivers within the supply-chain function, augmented by financial reports, Syspro databases at OMRMD, distribution records, health-facility records, logistics reports, transport schedules, expenditure records and invoices.

Baby-Mother-follow-up reports, made on a monthly basis, were used to identify the quantity of nevirapine syrup dispensed in every month for the period of five years under study (2012-2016). This variable is important because it indicates the utilisation of nevirapine at the facility level. This instrument is important; it establishes the utilisation

of nevirapine syrup for all facilities that provide services in preventive mother-to-child transmission (PMTCT).

Stock cards were also used as a research instrument to identify the quantities of medicine and diagnostic test kits received at, and issued from, a medical store. A stock card is usually used by a stock controller in health-center or clinic level. This research instrument tracked the utilisation of medicine and diagnostic test kits, safety stocks and maximum stocks at health centers and clinics in Oshana region.

Invoices were used by the researcher to identify the amount charged for NVP syrup or mRDT per unit at a facility. This research instrument helped to identify the cost of quantities of medicines and diagnostic tests that were ordered, issued and actually utilised or expired.

Malaria weekly data for district-health reports were used as a research instrument to identify the number of patients who tested for malaria and also the number of mRDT used for that testing. By means of data carried on these reports, the researcher was able to quantify the monthly consumption of mRDT in the region.

Delivery notes were used as a research instrument to determine the quantity of medicine and diagnostic test kits ordered by health facilities and the quantity issued by OMRMD. The delivery lead time can also be established with delivery notes.

District Health information system (DHIS2) this is a database with different health information in the districts. It was used to identify the prevalence and incidence of malaria and HIV among different groups of people in this study. DHIS2 was supplemented by Namibia health sentinel survey.

Monthly economic reports from the Namibia statistic agency (NSA) was used to identify the consumer price index or inflation for every month for the period of five years.

3.6.2 Data Collection Instrument for Informants

Unstructured interviews, comprised of guided questions, were used to interview informants and recorded in a voice recorder. In this study, data were collected for the period of two months starting from 9th July 2017 to 8th September 2017. A researcher was assisted to collect data from informants by a pharmacist assistant who was knowledgeable and experience in the pharmaceutical supply chain. These informants include people who hold different positions in the supply chain, and are able to give information on storage costs, orders, transportation costs, issuing or dispensing of medicine and safety stock levels. Qualitative data was captured by using a voice recorder in depth interviews which conducted between a researcher and informants and transcribed in written form for further study.

A pharmacist assistant received a training of one day on how the data can be extracted from invoices, delivery notes and softwares, especially EDT and other documents and record them on the checklist. In this study one phase design procedure was used to collect the data.

The researcher started collecting data at OMRMD whereby, the letter of approval from the MOHSS to conduct research at OMRMD was submitted to the chief pharmacist, Oshana region. The aim, objectives and significance of conducting this study were clearly explained and researcher gave assurance of privacy of staffs by using the designed codes to present names of staffs who interviewed and confidential information from documents reviewed were kept in safe and locked place. After detailed and comprehensive verbal

explanation, the chief pharmacist agreed, the researcher to start collecting data at OMRMD.

3.7 Pre-Testing the Study

The researcher conducted a pre-test study in the Oshikoto region at Onandjokwe hospital, Onayena health center and Oshigambo clinic. In order to test validity and reliability of the instruments Onandjokwe hospital was chosen as a pre-test site because it is the largest hospital in Oshikoto region. Sometimes Onandjokwe hospital supplies medicines to health clinics in Oshikoto region as well. Onandjokwe hospital's supplying medicines to clinics resembles the activity of OMRMD in Oshana region. Onayena health center and Oshigambo clinic were chosen by the researcher because they are closer to Onandjokwe hospital, not more than 10 kilometers away. Both health centers and clinics provide PMTCT services and malaria treatment. Onandjokwe hospital receives medicines directly from OMRMD.

All research instruments were tested, including the nevirapine register book, stock cards, Syspro, EDT, malaria weekly surveillance reports, baby-mother-follow-up report, and checklist (which was used to fill in variables extracted from research instruments listed above) and the interview description sheet used to guide were pre tested.

3.7.1 Pre-test Findings

As a research instrument, Facility Electronic Stock Cards (FESCs) were found not to be useful because they had been introduced only a few months prior to launching this study. Many staff members had yet to be trained on the system and how it works. For this reason, a lot of information regarding consumption issues had not yet been captured in

the FESC system. Due to the fact that the main orders of the hospital are processed by the Central Medical Store (CMS) and not OMRMD, the hospital was removed as a study site in the pre-test and retained with health centers and clinics. Many stock cards were missing in health facilities, and those that were available did not contain entries for amounts of maximum stock, safety stock and unit price. Despite, this deficiency, the stock card was used as a research instrument. The maximum stock variable was calculated using the formula: Reorder Level (ROL) plus Reorder quantity (ROQ) minus (Daily usage x lead time in days), i.e. ROL + ROQ – (Daily Usage x Lead time in Days). ROL = (maximum daily usage rate x lead time) + Safety stock. Safety stock was calculated using the formula, $Z \times \sigma LT \times D$ avg, where Z is the service level (Service level = (number of items issued ÷ number of items requested) × 100. The abbreviation, σLT, is the standard deviation of lead time and D avg is average demand.

In case the stock cards were missing, the researcher decided to use the order books from the health facilities to extract quantities of initial stock. Stock on hand at the time of order was regarded as the initial stock at the time the order was received.

Other useful research instruments after pretest were Baby –mother follow up reports, Nevirapine register book, Syspro, EDT and malaria weekly surveillance reports.

Malaria diagnostic test kits and nevirapine syrup consumption were also reviewed. For a drug whose consumption was considered inappropriate, the observed quantity consumed was adjusted using exponential smoothing. The adjustment is calculated for projected consumption by factoring in the average consumption for a three-month lead time, the consumption from the previous month, and the smoothing factor, alpha (α).

The checklist which was used to fill in variables extracted from research instruments listed above and interview description sheet used to guide were pre-tested (See appendix 9-11). Due to scarcity of adequate information regarding the holding cost information in public health facilities, the researcher estimated holding costs at 25% as a rule of thumb (105).

3.8 Research Instruments used in the Main Study

After the researcher had evaluated factors of feasibility, estimated time and projected costs of the study, the following were selected as research instruments to serve the main study.

3.8.1 Research Instruments for Nevirapine Syrup

The baby-mother-follow-up report, submitted monthly, was used to identify the consumption of NVP syrup at all health facilities. This variable reports the quantity of NVP syrup administered to high-risk infants for specified periods of six weeks or longer. Nevirapine-syrup registers were used to identify stock received, initial stock and consumption. Reference was made to delivery notes to identify periods when NVP syrup was out of stock. This variable is important because it establishes how long periods that the demand for NVP syrup was not met were. Information on quantities ordered and received from OMRMD by a health facility was extracted from delivery notes. Complementing the Nevirapine register, order books were also used to identify initial stock.

Syspro software in Oshakati Multi-regional Medical Depot (OMRMD) was used to extract quantities of NVP syrup received by OMRMD from CMS and quantities issued

by OMRMD to various health facilities in the Oshana region. These variables are important because quantities received from CMS indicate the need for NVP syrup by OMRMD, while the quantities issued to indicate the need of NVP syrup by health facilities in the region. Syspro was also used to extract information on initial stock and expired quantities of NVP syrup at OMRMD, which are indicative of loss in volume and money at OMRMD.

The expiry form was used at health centers and clinics to identify the quantity of NVP syrup, which has expired. This is a valuable statistic as it reveals the loss of NVP syrup at the facility level. Delivery notes were used to identify stock-outs or shortages of NVP syrup, important because they indicate the quantity of NVP syrup missing from stock requirements at health facilities, i.e. unmet demand. Invoices were used to indicate unit prices of NVP syrup; important because discrepancies, or differences, in prices between syrup ordered, issued, consumed and expired can be calculated. Dispatch notes and delivery notes were used to identify delivery lead times, important because scheduled delivery of NVP syrup is a matter of urgency.

3.8.2 Research Instruments for the Malaria Rapid Test Kit (mRDT)

Malaria surveillance-data-collection sheets, completed on a weekly basis at all health facilities, were used to identify all cases of fever and the number of people tested for malaria. This variable is important because it indicates the number of mRDTs consumed at all health facilities in the region. Delivery notes were used to identify periods when mRDTs were out of stock. The variable is important because it shows how long the demand of mRDT was not met. Delivery notes also identify quantities received, priced and ordered from OMRMD. These parameters are important because they show the price,

demand at health facilities and the capacity of OMRMD to meet the demand of the health facilities.

Syspro software in at OMRMD was also used to extract a number of mRDT received by OMRMD from CMS, and quantity issued from OMRMD to various health facilities within the region. These variables are important because quantities received from CMS indicate the need for mRDT by OMRMD. Quantities issued indicate the need of 3TC by health facilities in the region. Syspro was also used to extract quantities of expired mRDT at OMRMD, indicating a loss in terms of volume and money wasted by OMRMD.

The number is important because it indicates the quantities of mRDT that are missing at a health facility necessary to fulfill the requirement (unmet demand for mRDT). Invoices were used to indicate the unit price of mRDT, important because it lists the costs of mRDT ordered, issued, consumed and expired. Dispatch notes and delivery notes were used to identify delivery lead times, important because prompt delivery of mRDT is a matter of urgency.

Checklists which record 13 variables extracted from the indicated research instruments, both for mRDT and NVP syrup were used at all study sites.

3.9 Data Collection

3.9.1 Procedure for Collecting Quantitative Data.

The first part, including collection of quantitative data from all health facilities. A researcher examined existing data from databases, document review and reports.

3.9.1.1 Oshana Mult-Regions Medical Depot

Researcher started collecting quantitative data at Oshakati Multi-Regions Medical Depot (OMRMD) with assistance of a senior pharmacist from OMRMD who is well experienced in Syspro software. From Syspro database, quantity of NVP syrup and mRDT for the period of 5 years (2012-2016) that expired, ordered, received, issued by CMS to OMRMD and from OMRMD to all health facilities (excluding Eloolo clinic) in Oshana region were extracted and transferred to the checklist. Other variables extracted from Syspro software were duration (delivery lead time), price and initial stock.

3.9.1.2 Health Centers (H/C)

In Oshana region, there are four health centers namely Oshakati health center which is within IHO, Ongwediva health center, Ounick health center, Okatana health center and Ondangwa health center. For the easier data collection, a researcher categorized health centers into two categories. H/Cs which uses EDT to capture quantity ordered, quantity received and consumption of Nevirapine syrup, in addition of nevirapine register. These are Ongwediva H/C and Ondangwa H/C. The other category is health centers, which don't use EDT (during the time of data collection), namely Ounick H/C, Okatana H/C and Oshakati H/C.

3.9.1.3. Health Centers with Electronic Dispensing Tool (EDT)

A data collector started collecting data at Ongwediva H/C. EDT database was used to extract quantities ordered, received, consumption and initial stock of nevirapine (NVP) syrup. Delivery notes were used to identify the delivery lead time; quantity ordered and received of NVP syrup and Malaria rapid diagnostic test (mRDT). The invoices were used to identify the prices of NVP syrup and mRDT. In case of NVP syrup delivery note

was complemented the data from EDT database. Since NVP syrup is under PMTCT program, some of the data were obtained from the NVP syrup register, which also complemented data from EDT database. The initial stock was also extracted from the ordering book, this was done so that to complement data from the EDT and the nevirapine register books. The same procedure was repeated at Ondangwa HC. All the variables extracted from the EDT database and other documents mentioned above were transferred to the checklist.

3.9.1.4. Health Centers without EDT

A data collector (Pharmacist assistant) used ordering books to identify initial stock of NVP syrup and mRDT. Delivery note used to identify the quantity of NVP syrup and mRDT ordered, received and delivery lead time from OMRMD to health centers. Since NVP syrup is used mostly in Preventive Mother to Child Transmission (PMTCT) program, nevirapine syrup register books from PMTCT was also used to identify consumption of NVP syrup and initial stock. The ordering books were used to identify initial stock of NVP syrup and mRDT. This complemented the nevirapine register books. The invoices were used to identify the price of NVP syrup and mRDT. This collection procedure was done in Ounick, Okatana and Oshakati health centers. All the variables extracted from the documents mentioned were transferred into the checklist.

3.9.1.5 Health Clinics

In clinics the researcher and data collector used the delivery note to extract the quantity of mRDT and NVP syrup ordered and received from OMRMD for the period of 2012-2016. The ordering books were used to identify the initial stock of NVP syrup and mRDT. In case of NVP syrup, The nevirapine (NVP) syrup register books were also used

to identify the initial stock and consumption of NVP syrup. Expired forms were used to identify the quantity of expired items. The health clinics visited for data collection were Eluwa, Onamutayi, Uuukwiyuushona, Ekamba, Ehafo, Eheke, Oukamasheshe and Okaukedjo. All data extracted and calculated the estimated cost was transferred into the checklist. All variables extracted were transferred into the checklist. In addition, of the consumption data collected from the health facilities as mentioned above. A researcher decided to collect the overall reports of consumption data of mRDT and NVP syrup in the district as follows:

3.9.1.6 Primary Health Care-Oshana District

A researcher collected data on consumption of nevirapine syrup for all health facilities in Oshana for the period of five years (2012-2016) through the overall baby mother follow up reports. These reports were obtained from the office of the Primary Health Care (PHC) supervisor and the office of the Principal Medical Officer (PMO). The aim of collecting all data of consumption of Nevirapine syrup from all health facilities was to complement the consumption data collected by other documents. The variable was then transferred to the checklist.

3.9.1.7 Special Program Malaria and HIV-Oshana Region

A researcher collected data on the consumption of malaria test kits (mRDT) for the all health facilities in Oshana from 2012-2016 through Malaria weekly data for health facility reports. These data were obtained from the office of coordinator of special programs in Oshana region. The consumption of mRDT was transferred to the checklist.

3.9.1.8 Others

Prevalence and incidences of the diseases were obtained from DHIS2 and NHSS. Consumer price index (CPI) which show inflation rate was extracted from monthly economic reports and entered in the checklist.

3.9.2 Procedure for Collecting Qualitative data.

Due to the fact that the essential medicine supply chain is a very complex matter, the researcher conducted individuals face to face contact semi-structured interview with informants. In this case a researcher did not follow predetermined questions. The audio tape recorder and notes were used by a researcher to record the meaningfulness of informants' perspectives and experiences by their own words during the interview. The duration of interview with informants ranges from 30 minutes to one hour. Qualitative data was captured by using a voice recorder in depth interviews which conducted between a researcher and informants. The interview was transcribed in written form for further study. The document was created related to the research procedures, which used to describe data analysis method. Participants' words were used as codes when possible by creating the free codes. Data was assigned preliminary codes in order to describe the content and then same patterns or themes in the codes across the different interviewees were identified, reviewed and named.

3.10 Data Analysis

Data analysis was categorized into two parts, namely quantitative part and qualitative part. In an analysis of quantitative data the following statistical methods were used;

Simple linear regression analysis using SPSS was used in time series for the forecasting consumption of mRDT and NVP syrup at health facilities. To smooth out the variation in the time series trend of mRDT and NVP syrup, the moving average technique was used. A simple linear regression method provided a complementary approach to the consumption of mRDT and NVP syrup. The models also assess the relationship between independent and dependent variables. The model also determined different probability distributions of NVP syrup and mRDT at health facilities. Then different distributions were adjusted to specific probability distribution.

Binary logistic regression was used in order to identify the factors associated with stock out of mRDT and NVP syrup with the assumption that there were no outliers. This allows researchers to investigate complex supply chain concepts that are not easily measured directly by collapsing a large number of variables into a few interpretable underlying factors. Another part of the analysis was qualitative part, which a researcher used thematic analysis, this was very important so that to address the research objectives in the broader picture.

3.11 Reliability and Validity of Quantitative

A pretest was conducted to identify any possible practical problems, consistency and to ensure that the research tools and checklist were easy to understand and complete. While

reliability is necessary, it alone is not sufficient. For a test to be reliable, it also needs to be validated

The researcher used the same checklist for each item in all study sites. The key guide questions were asked in the exactly the same order and in the same way in order to maintain consistence. All these measures were supported by the computation of Cronbanch's alpha coefficient using SPSS version 24. The Cronbanch's alpha coefficient was 0.8.

3.11.1 Trustworthiness in Qualitative Part of a Mixed Method

Trustworthiness is all about establishing credibility, transferability, confirmable, and dependable of the research findings. The researcher used triangulation to show the research study's findings are credible. To ensure transferability a researcher used thick description to show that the research study's findings can be applied to other contexts, circumstances, and situations. For confirmability a researcher provided an audit trail, which highlights every step of data analysis that was made in order to establish that the research study's findings are accurately portrayed participants' responses.

3.12 Ethical Consideration

The study applied the following three fundamental ethical principles: firstly, the researcher sought the ethical clearance from the University of Namibia Research Ethics Committee (UREC) and Ministry of Health and Social Services (MoHSS). Permissions to conduct research was also received from Oshana Regional Health Directorate and from respective study sites. A researcher obtained written consent from informants by giving accurate and complete information regarding the purpose of the study, their

responsibilities and the benefits and risks of the study. This was done prior to the study to ensure that informants understood the proposed research. The researcher ensured privacy and confidentiality by making sure that health facility's identity, information or names of informants is anonymous during the collection and stored in a researcher's personal computer and protected by a password which is only known by a researcher. Reporting of results or in any publication should be honest and integrity. Ultimately destroying of data should be done in an irreversible way in such a way that data cannot be retrieved and reused.

3.13 Summary

Chapter 3 contained a detailed explanation of the research design and methodology were fully explained. These include how data in two phases, i.e. quantitative and qualitative were collected in health facilities. Measures to ensure reliability, validity, trustworthiness and ethical consideration were discussed. Quantitative data were entered into SPSS version 24 and analysis carried out. The qualitative data were analyzed manually by identifying themes and sub themes. The following chapter 4 dealt with the results.

CHAPTER 4: RESULTS

PART A: Results for Malaria Diagnostic Test Kit (mRDT)

4.1a Introduction

Part A, of chapter four presents quantitative and qualitative findings of mRDT. The findings consist of time series in which different patterns were identified and consumption rates calculated in quarter. Quantitatively, factors which are statistically significant associated with stock out were triangulated with qualitative factors which are linked to stock out. The qualitative factors were obtained from sub themes. Predictors of stock out were used as a basis to develop a stock level model of mRDT. The potential model developed was verified validated and illustrate how well the model depicts the condition of the real world. This was done by means of simulation

4.2a Consumption and Trends of mRDT

4.2.1a Consumption rates and trend of mRDT at OMRMD.

Figure 8, shows there was a very sharp increase in consumption of mRDT in quarter three of 2016. However, consumption of mRDT shows a positive secular trend with cyclic and seasonal movement. The positive secular trend is shown by the equation ($y = 289x + 3916$). CMA indicates the smooth out of the variation of mRDT consumption.

Note. Cm is consumption of mRDT, CMA is central moving average

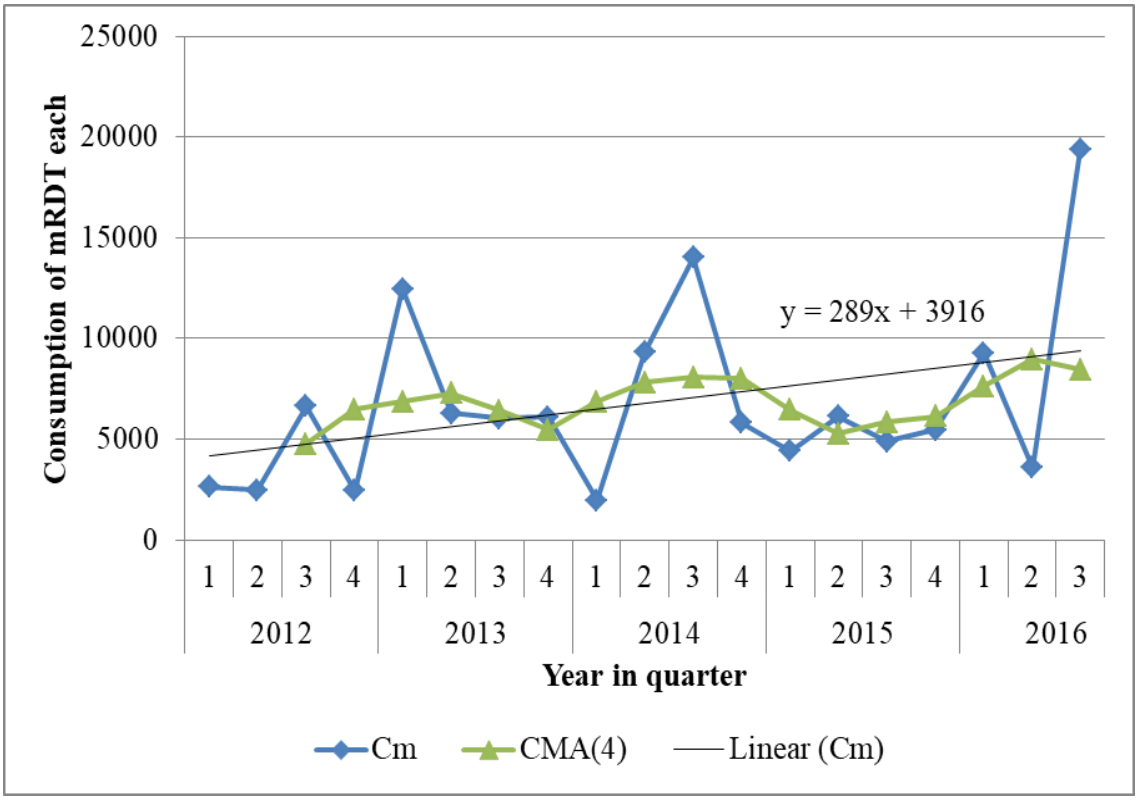


Figure 8. Time series trend of mRDT consumption at OMRMD and centered moving average (baseline) in quarterly basis.

The following is table 1, which indicated the consumption for Malaria test kit (mRDT) at OMRMD. The table comprises the smoothing (MA and CMA), deseasonalize and forecasting consumption of mRDT. Note that the unit of issue (consumption) of mRDT is each test. One pack of mRDT contains 25 tests**.** Quarter two and four are below the baseline (CMA) by 8% and 22%, respectively, and quarter three is 44% above the baseline while quarter one is exactly the same as the baseline.

Note: In table 1, MA (4) is a moving average of four periods. CMA (4) is a centered, moving average of four periods. S_t is the seasonal trend, I_t is irregular trends, C_m is the consumption of nevirapine syrup at OMRMD in over a quarter and T_t is the time trend.

Table 1. Quarterly consumption of mRDT and forecasting at OMRMD.

		Y_t			Y_t /C M A		Y_t/S_t		
t	Year Quarter	C_m	MA(4)	CMA(4)	S_t,I_t	S_t	Deseaso nalize	Tt	Forecasting
1	2012Q1	2625				1	2625	5008.39	5008.39
2	2012Q2	2475				0.91	2719	5134.67	4672.55
3	2012Q3	6625	3537.5	4765.63	1.39	1.44	4600	5260.95	7575.76
4	2012Q4	2425	5993.75	6471.88	0.37	0.78	3108	5387.23	4202.04
5	2013Q1	12450	6950	6878.13	1.81	1	12450	5513.51	5513.51
6	2013Q2	6300	6806.25	7265.63	0.87	0.91	6923	5639.79	5132.21
7	2013Q3	6050	7725	6412.5	0.94	1.44	4201	5766.07	8303.14
8	2013Q4	6100	5100	5478.13	1.11	0.78	7820	5892.35	4596.03
9	2014Q1	1950	5856.25	6853.13	0.28	1	1950	6018.63	6018.63
10	2014Q2	9325	7850	7812.5	1.19	0.91	10247	6144.91	5591.87
11	2014Q3	14025	7775	8084.38	1.73	1.44	9739	6271.19	9030.51
12	2014Q4	5800	8393.75	7993.75	0.73	0.78	7435	6397.47	4990.03
13	2015Q1	4425	7593.75	6453.13	0.69	1	4425	6523.75	6523.75
14	2015Q2	6125	5312.5	5271.88	1.16	0.91	6730	6650.03	6051.53
15	2015Q3	4900	5231.25	5837.5	0.84	1.44	3402	6776.31	9757.89
16	2015Q4	5475	6443.75	6128.12	0.89	0.78	7019	6902.59	5384.02
17	2016Q1	9275	5812.5	7621.88	1.22	1	9275	7028.87	7028.87
18	2016Q2	3600	9431.25	8950	0.4	0.91	3956	7155.15	6511.19
19	2016Q3	19375	8468.75	8468.75	2.29	1.44	13454	7281.43	10485.26
20	2016Q4	1625				0.78	2083	7407.71	5778.02
21	2017Q1					1		7533.99	7533.99
22	2017Q1					0.91		7660.27	6970.85
23	2017Q2					1.44		7786.56	11212.64
24	2017Q3					0.78		7912.84	6172.01
28	2017Q4					0.78		8417.96	6566.01

4.2.2a Consumption rates and trend of mRDT at health centers.

The figure 9, showed the trend of mRDT consumption and the baseline (CMA) after smoothing

The figure 9, showed that there is variation in trend for consumption of mRDT at HCs in Oshana region. The trend indicated both cyclic characteristics. The series as the previous ones appear to wander up and down. No any outliers. The graph showed that, there is a positive secular trend with cyclic which is indicated by the line with equation y = 160x +170

Note C_{mh} is consumption of mRDT at health centres. CMA (4) Central Moving Averge in the quarter.Consumption of mRDT at health centers (HCs) was based on the number of patients who tested for malaria as per malaria guideline (14).

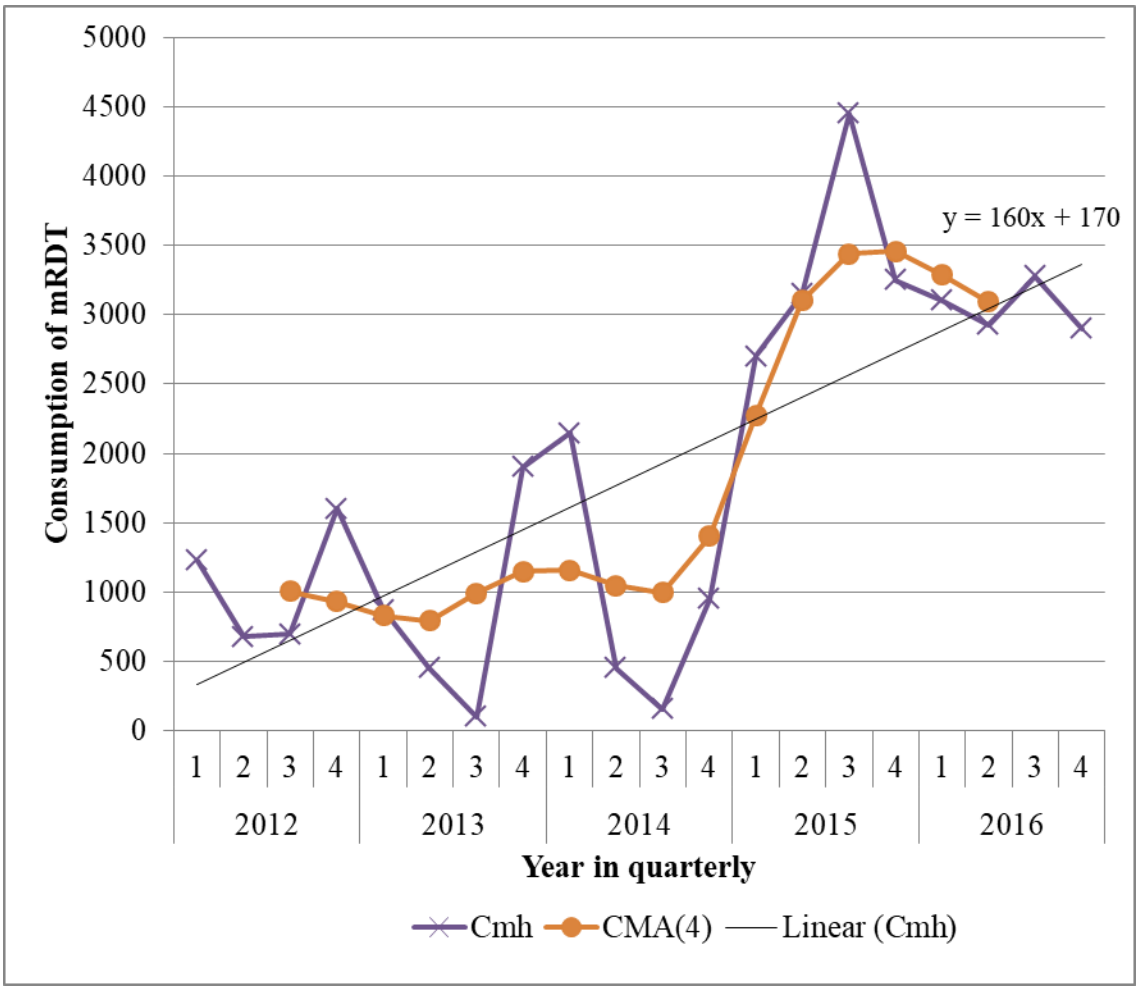


Figure 9. Time series trend of mRDT consumption and centered moving average (baseline) in quarterly basis at HCs.

4.2.2.1 Time series analysis of mRDT at HCs

Below is the table 2, for time series analysis of mRDT at health centers. As other table above, CMA(4) was used to smooth the variation of consumption data. Classical multiplicative model ($Y_t=S_t$ x I_t x T_t) was used to get seasonal and irregular components and simple linear regression was used to calculate the forecasting and assess the fitness.

The red numbers (values) indicate consumption of forecasted for the period of 2017-2018.

Note: MA (4) is moving average of four periods, CMA(4) is centered moving average of four periods. S_t is seasonal trend, I_t is irregular trends, C_{mh} is consumption of malaria test kit at health centers in quarterly and T_t is time trend. The table in a S_t column show that in quarter two and three of each year, 26% and 16% of the consumption of mRDT are below the baseline.

Table 2. Quarterly consumption of mRDT and forecasting at health centres.

		Y_t			Y_t/CMA		Y_t/S_t		
t	Year Quarter	C_{mh}	MA(4)	CMA(4)	S_t, I_t	S_t	Deseasonalize	T_t	Forecasting
1	2012Q1	1225				1.26	972	203.11	255.92
2	2012Q2	675				0.74	912	378.36	279.99
3	2012Q3	695	1048.75	1004.37	0.69	0.82	847	553.61	453.96
4	2012Q4	1600	960	931.87	1.72	1.25	1280	728.86	911.08
5	2013Q1	870	903.75	829.37	1.05	1.26	690	904.11	1139.19
6	2013Q2	450	755	792.5	0.57	0.74	608	1079.37	798.73
7	2013Q3	100	830	989.62	0.1	0.82	121	1254.62	1028.79
8	2013Q4	1900	1149.25	1149.25	1.65	1.25	1520	1429.87	1787.34
9	2014Q1	2147	1149.25	1156.25	1.86	1.26	1703	1605.12	2022.45
10	2014Q2	450	1163.25	1044.62	0.43	0.74	608	1780.37	1317.48
11	2014Q3	156	926	995.12	0.16	0.82	190	1955.63	1603.61
12	2014Q4	951	1064.25	1401.75	0.68	1.25	760	2130.88	2663.59
13	2015Q1	2700	1739.25	2276	1.19	1.26	2142	2306.13	2905.72
14	2015Q2	3150	2812.75	3100.25	1.02	0.74	4256	2481.38	1836.22
15	2015Q3	4450	3387.75	3437.75	1.29	0.82	5426	2656.63	2178.44
16	2015Q4	3251	3487.75	3459.62	0.94	1.25	2600	2831.88	3539.85
17	2016Q1	3100	3431.5	3284.62	0.94	1.26	2460	3007.13	3788.99
18	2016Q2	2925	3137.75	3093.87	0.94	0.74	3952	3182.38	2354.96
19	2016Q3	3275	3050			0.82	3993	3357.63	2753.26
20	2016Q4	2900				1.25	2320	3532.89	4416.11
21	2017Q1					1.26		3708.14	4672.25
22	2017Q2					0.74		3883.39	2873.71
23	2017Q3					0.82		4058.64	3328.08
24	2017Q4					1.25		4233.89	5292.36

4.2.3a Consumption rates and trend of mRDT at the Clinics

Figure 10, showed that there is variation in trend for consumption of mRDT at clinics in Oshana region. The trend indicated seasonal and cyclic characteristics. The series appears to wander up for a long time. No any outliers. The graph shows that, there is a positive

secular trend with seasonality and cyclic. The positive secular trend is shown by the equation y =57x +71. Note C_{mc} is consumption of mRDT at clinics.

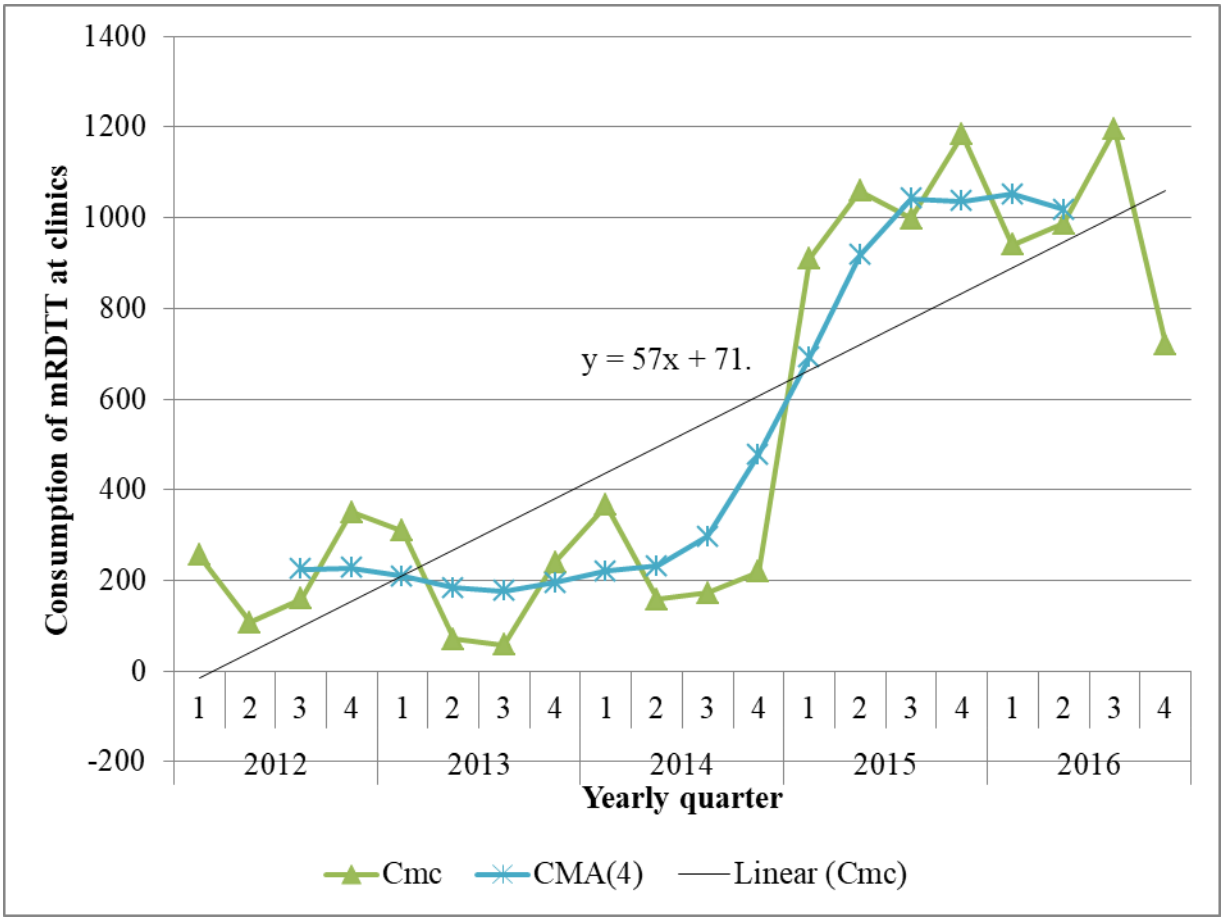


Figure 10. Times series for consumption of mRDT and centered moving average (CMA) at clinic.

4.2.3.1 Time Series Analysis of Consumption of mRDTat the Clinic

Consumption of mRDT at the clinics as in the health centres was based on the patients tested for malaria as per guideline. Table 4.3, showed time series analysis of mRDT at clinics, as in the other table above, CMA(4) was used to smooth the variation of consumption data. Classical multiplicative model ($Y_t=S_t \times I_t \times T_t$) was used to get seasonal and irregular components and simple linear regression was used to calculate the

forecasting and assess the fitness . The consumption data on red indicate consumption of mRDT forecasted for the period of 2017-2018 at the clinics.

Note: MA(4) is moving average of four periods, CMA(4) is centered moving average of four periods. S_t is seasonal trend, I_t is irregular trends, C_{mc} is consumption of mRDT quarterly and T_t is time trend. The table in a S_t column show that in quarter two and three of each year,consumption is low by 20% and 35% respectively from the baseline. This is illustrated in table 3 below.

Table 3. Quarterly consumption of mRDT and forecasting at clinics.

		Y_t			Y_t/CMA		Y_t/S_t		
t	Year	C_{mc}	MA(4)	CMA(4)	S_t, I_t	S_t	Deseasonalized	T_t	Forecasting
1	2012Q1	256				1.33	192	70.53	94
2	2012Q2	107				0.8	133	2.08	167
3	2012Q3	160	218.5	225.12	0.71	0.65	246	66.36	43.14
4	2012Q4	351	231.75	227.12	1.55	1.08	325	134.81	145.59
5	2013Q1	309	222.5	209.75	1.47	1.33	232	203.25	270.32
6	2013Q2	70	197	183.25	0.38	0.8	87	271.7	217.36
7	2013Q3	58	169.5	176.62	0.33	0.65	89	340.14	221.09
8	2013Q4	241	183.75	194.75	1.24	1.08	223	408.59	441.27
9	2014Q1	366	205.75	220.12	1.66	1.33	275	477.03	634.45
10	2014Q2	158	234.5	231.75	0.68	0.65	243	545.48	354.56
11	2014Q3	173	229	297.12	0.58	0.65	266	613.92	399.05
12	2014Q4	219	365.25	477.87	0.46	1.08	202	682.37	736.96
13	2015Q1	911	590.5	693.62	1.31	1.33	684	750.81	998.58
14	2015Q2	1059	796.75	917.375	1.15	0.8	1323	819.26	655.41
15	2015Q3	998	1038	1041.62	0.96	0.65	1535	887.7	577.01
16	2015Q4	1184	1045.25	1036.25	1.14	1.08	1096	956.15	1032.64
17	2016Q1	940	1027.25	1051.87	0.89	1.33	706	1024.59	1362.71
18	2016Q2	987	1076.5	1018.5	0.97	0.8	1233	1093.04	874.43
19	2016Q3	1195	960.5			0.65	1838	1161.48	754.96
20	2016Q4	720				1.08	666	1229.93	1328.32
21	2017Q1					1.33		1298.37	1726.84
22	2017Q2					0.8		1366.82	1093.45
23	2017Q3					0.65		1435.26	932.92
24	2017Q4					1.08		1503.71	1624.01

4.3a Factors associated with stock out of mRDT

Different variables were considered to find a correlation with stock out by using coefficient correlation of Pearson and binary logistic regression analysis was used to find out the predictive factors which predict stock out of mRDT.

4.3.1a Factors associated with stock out of mRDT at OMRMD

Table 4 showed that quantity of mRDT ordered by OMRMD from CMS is statistically significant associated with stock out of mRDT. Rainfall is marginal statistically associated with stock out are statistically significant associates with stock out of mRDT at OMRMD.

Table 4. Factors affecting the stock out of mRDT at the OMRMD.

Factors		Suspected malaria under five	Malaria incidence	Suspected malaria cases over five	Malaria prevalence	Total suspected malaria cases	Death due to malaria	All patients tested for malaria	Initial Stock	Quantity ordered	Quantity Received at OMRMD	Delivery Lead Time	Average Temperature °C	Rainfall in mm	Economy-Inflation Rate
Stockout	Pearson Correlation	-.182	-.089	-.180	-.011	-.181	-.103	-.181	-.129	-.130	-.069	.285*	.307**	.388**	.049
	P value	.082	.251	.085	.467	.083	.218	.083	.163	.161	.300	**.014***	**.009***	**.001***	.356

Table 4, indicates that delivery lead time, average Temperature and rainfall is statistically significant associated with stock out of mRDT at OMRMD.

4.3.2a Factors associated with the stock out of mRDT at health centres.

Table 5 indicated that, the average temperature and rainfall is statistically significant associated with stock out of mRDT at the health centres.

Table 5. Factors affecting the stock out of mRDT at the HCs.

Stockout		
P Value	Pearson Correlation	Consumption HC
.487	-.091	
.017*	.307*	Average Temperature °C
.002*	.388**	Rainfall in mm
.712	.049	Inflation Rate
.164	-.182	Suspected Cases Malaria under five
.501	-.089	Incidence Malaria per100
.935	-.011	Malaria Prevalence per100
.165	-.181	Total Suspected Malaria Cases
.169	-.180	Malaria cases over 5
.435	-.103	Death due Malaria
.165	-.181	All patients tested for malaria
.327	-.129	Initial Stock
.720	-.047	Quantity ordered HC
.303	-.135	Quantity issued HC
.846	.026	Delivery lead Time

Table 5 indicated that Average temperature and rainfall are the factors associated with stock out of mRDT at Health Centre.

4.3.3a. Factors associated with Stock out of mRDT at the clinics

Table 6, indicates that average temperature, rainfall and delivery time are the factors associated with stock out of mRDT.

Table 6. Factors affecting the stock out of mRDT at the clinics.

		Average Temperature C	Rainfall in mm	Economy-Inflation Rate	Suspected Cases Malaria under five	Incidence Malaria	Malaria Prevalence	Total Suspected Malaria Cases	Suspected Cases Malaria Over five	Death due Malaria	All patients tested for malaria	Initial Stock	Quantity ordered Clinics	Quantity issued Clinics	Delivery lead time	Consumption clinic
Stockout	Pearson Correlation	.307*	.388**	.049	-.182	-.089	-.011	-.181	-.180	-.103	-.181	-.129	-.047	-.135	.026	-.017
	P value	**.037***	**.042***	.712	.164	.501	.935	.165	.169	.435	.165	.327	.720	.303	**.021***	.897

4.3.4 Description of Informants

A total of 17 informants were interviewed. Informants' experiences in supply chain range from 2 years to 21 years, and the highest level of education of informants attained range from certificate to the degree level.

4.3.4.1 Thematic Analysis

Basically, one theme of description reflecting key variations of meaning emerged from the analysis. The commonalities and variations in informants descriptions are illustrated with excerpts from the transcripts. The quotes provide illustrative examples of the theme that supplement the excerpts description. There were sub-themes that came out from the emerged theme.

Table 7. Outline of informants for qualitative part

Types of respondents.	**Theme**	**Tool**	**Number**	**Total.**
Managers and decision makers in pharmaceutical supply chain and special program (Malaria and HIV).	Causes of the stock out, consumption and the view of the policy on mRDT and NVP syrup.	Informant interview	3	3
Pharmacists	Factors which are associated with stock out of mRDT and NVP syrup in public health facilities.	Informant interview	5	5
Pharmacist assistant.	Factors which are associated with stock out of mRDT and NVP syrup in public health facilities.	Interview formants	1x3 health facilities.	3
Registered nurses	Challenges and factors associated with stock out of mRDT and NVP syrup.	Informant interview	1x4 health facilities.	4
Transport officer and drivers.	Challenges of transport in delivery of mRDT and NVP syrup.	Informant interview	2	2

4.3.4.2 Theme and Sub themes

Basically one theme of description reflecting key variations of meaning emerged from the analysis. The commonalities and variations in informants' descriptions are illustrated with excerpts from the transcripts. The quotes provide illustrative examples of the theme that supplement the excerpts description. There were sub-themes that came out from the emerged theme. Stock out theme derived from informants is illustrated in the table below:

Table 8. Themes and Subthemes.

Themes	Sub themes
Theme 1 Stock out	1 a: mRDT consumption 1b: NVP Syrup consumption Improper ordering Lack of consumption data/over consumption. . Expired medicine/short dated medicine received**.**
	Storage capacity Lack of transparency in pharmaceutical supply chain. . Lack of proper preparation during implementation of a policy/guidelines
	Pharmaceutical knowledge. Shortage of trained staff in pharmaceutical. Doing double tasks(task shifting) Poor documentation/record keeping Lack of transparency and communications
	Delivery lead time Transportation of pharmaceutical items. Delays in delivery of items.

Theme 1. Stock Out of mRDT and NVP syrup.

As it was mentioned on the statement problems that despite of improvement of supply chain of essential medicines these medicines have been sporadically reported that they are out of stock. The informants from managerial level to the clinic level also mentioned the sporadic stock out of these medicines from 2012-2016. In the interview of key informants the following sub themes emerged from the main theme as follows

Sub theme 1a & 1b. mRDT consumption and NVP Syrup consumption.

This core category describes the consumption of mRDT and NVP syrup. Although the majority informants pointed out a poor estimation of consumption of NVP syrup and mRDT in health facilities, there are some who reported that they have no problems regarding NVP stock out but only mRDT. This is evident form this statement:

"We do not have problems with medicine only with test kits."

However there are those who indicated that they experience problem with stock out for both medicines and mRDT. One informant raised concerns that:

" *Patients go without being diagnosed, given wrong treatments because we cannot give right treatment if we do not know what is wrong with the patient."*

They assume that this could be due to lack of proper coordination and feedback to all stakeholders who are involved in the pharmaceutical supply chain. Informants feel that there is a need to reconsider or strengthen the way consumption of NVP syrup, mRDT and other medicines are estimated and adjusted.

Sub theme 1.2. Improper ordering and recording

The outcome of poor estimation of consumption is overstock or understock, expired medicines, hence compromise the quality of medicines itself and provision of services. In this category, the emphasis was mainly on the quantification of medicines at the regional level and what is the experience and the proper procedure to be followed here in Oshana region. One informant indicated that there are standard procedures which supposed to be followed. This is evident from this statement:

"There are SOPs and that is what we follow, but sometimes we receive medicine 3 weeks after ordering, that leads us not to meet needs of customers."

Most informants explain their experiences and the views on proper procedures in quantification/ consumption were observed in the excerpts that follow:

"Quantification of consumption of medicines at OMRMD is totally based on what we are issuing to health facilities, that is not a 100% proper way/procedure, I would like to see in the future, we are also getting reports of real consumption of medicines from the level of the clinic to the level of hospital (dispensing areas or from the patient register book), there is where the actual consumption of medicines occurs. We can use those reports as a launching pad of the quantification process."

Some informants reported that there is a system in place and they assume that the system helps the facilities to order the correct stock, but that is not the case. They have this to say:

"We are assuming that what the health facility is requested is exactly what it needs, but that is not the case, because most of health facilities, especially clinics are requesting more than or equivalent to a health center or sometimes equivalent to hospital consumption!!. Therefore, based on the issuing alone does not reflect a true picture on the ground, though it is easy and not time consuming."

Requesting more than what is needed leads to overstock and results to wastage as medicines will expire before consumption. It is evident from the expression of some informants below:

"My biggest concern is the rate of expired medicine and wastage (NVP syrup and mRDT) due to overstock. Using the software like FESC (Facility electronic stock card) does not help100% to quantify exactly what we are consuming. Lack of proper consumption data has resulted to have more medicines which are expired and also run out of stock because of under estimate of consumption."

"We are ordering based on the ordering schedule which we received from OMRMD but the technique or what should we consider before ordering, we don't know!".

The informant at the medical store has a different experience as it is indicated below:

"We are really doing well, every week we deliver to two hospitals; order processing time is 100%"

Nonetheless there are different views regarding proper consumption data as some informants have this to say about consumption reports:

'"I always receive consumption reports of mRDT and NVP syrup in a monthly basis, but there is no system in place to give feedback of these reports to OMRMD, I think that is a weakness. But we always communicate with OMRMD in case of shortage and other issues related to NVP syrup and mRDT".

"Where there are pharmacy assistants and pharmacists, recording is done very well, unlike where there are nurses who have a lot of work."

Sub theme 1.3. Receiving Short Dated Items.

The majority of informants expressed the same view regarding the short dated medicines

Findings from interviews show that there is a problem of receiving short dated items. Informants had to say this:

"It is not uncommon to receive NVP syrup or mRDT which is less than 6 month to expire and thus contribute to the stock out of medicine."

According to the drug policy the medicine (mRDT and NVP syrup) received from medical store should be more than 6 months to expire (65).

Sub theme 1.4. Storage Capacity.

Storage facilities need to be of an appropriate size to store sufficient mRDT and NVP syrup to meet demand, taking account of the following factors, that is levels of safety stock to be held, frequency of onward delivery to lower level stores or health facilities, patient demand, taking account of seasonal and other fluctuations in consumption, seasonal re-supply factors, such as road closures caused by flooding and the like. In the case of an existing storage facility, decisions regarding above factors are in turn affected by the actual storage capacity of the building and the opportunities available for reorganization or expansion.

The informants at all levels stated that *"The storage space has always been a problem, and this makes some health facilities to pile up boxes on the floor, this practice can compromise the quality of medicines".*

"*Because of the limited storage and improper arrangement you will find that the medicines are ordered and receive, but don't use, but the staff realized that medicine was there, but have already gotten expired".*

"*The biggest challenge is the space for storage that makes us to place the items on different places and it is also time consuming."*

Although the majority of informants reported storage as a challenge in their facilities, there is one informant who differs from the others and that is evident from the following statement:

"*There is no challenge of space for starage because we have a big storage at our facility."*

Sub theme 1.5: Pharmaceutical knowledge

Procurement is a very important stage of the supply chain of medicines. Most of the informants said *"Although am not dealing with procurements there is a lot of challenges when it comes to procurements. If the procurement process will not involve all the stakeholders in supply chain definitely will result to stock out".*

Regarding procurement process one informant reported as follows:

"We order, but we do not receive according to our demand. Sometimes there are no medicine at medical store, but at my level we cannot solve the problem."

The informant at regional medical store reported that: "Regarding *the procurement, there is a weakness in inventory management, which is mostly done by nurses who do not have much knowledge. We plan to train them properly.""" We cannot control the quantity, it is*

the responsibility of the health facilities supervisors. But sometimes the clinics order the same amount like the hospital. However sometimes we call them to confirm if they really need the quantity they order."

The interview on the issue of procurement was not in the details, because the procurement of medicine is done at the national level and not at the regional level.

Sub Theme 1:6. Medicine Policy and Decision Makers

This theme represents the importance of policy and decision making in the pharmaceutical supply chain, it focuses on how the key informants in supply chain view the impact of policy on the supply chain. The basic goals of national medicine policies and public-sector pharmaceutical supply systems are to provide access to needed medicines and supplies, promote the rational use of medicines, and ensure the quality, safety, and efficacy of medicines. Various strategies exist to achieve these goals through different combinations of public and private involvement in the pharmaceutical management cycle. National systems vary with respect to public and private roles in financing, distribution, and dispensing of pharmaceuticals, ranging from fully public to fully private systems (61).

All the informants from the management level to the clinic level admitted the challenges they are facing when new policy or guidelines are introduced without a proper communication with the people who are more in operation levels.

"Will just receive information like start implementing new guideline, without consider if staffs are trained and all materials/ pharmaceutical are available to carry out such activities."

Sub theme 1.7. Lack of Transparency in Pharmaceutical Supply Chain

For a supply chain to operate effectively in today's global world, transparency is a prerequisite. Transparency, improve and strengthen the supply chain by making this information readily available to all stakeholders, so as to enable a quick response to any shocks to the chain. It means that demand can be reshaped and supply redirected whenever, and however, it is necessary to do so.

Having a transparency in the pharmaceutical supply chain may cut risks, improve speed to market, and help identify shortage and quality problems along the supply chain, yet many institutions dealing with pharmaceutical supply chain are failing in their duty to enforce it. The key to transparency is to provide controlled access and accurate events and data in a timely fashion. This data includes transactions, content and relevant supply chain information, not only between the different organizations involved, but also different departments within an institution. The cloud is having a massive impact in providing access to all of this, as is data collection and analysis software and it is useful to have a single interface which is accessible by everyone who needs access. Supply chains have long suffered from data silos, and these need to be freed up as a matter of course to help manage demand signals more accurately and reduce inventory levels, answer customers' requests faster and more accurately, and improve demand variation.

Another vital part of ensuring good transparency is communication. For this communication to work efficiently though, trust is paramount, as is developing a good relationship with your suppliers/distributor. Informants had this to say:

"Sometimes there is no communication between the management and other lower levels, e.g some time people from management level can come for supportive supervision once in a year. And most of the time we are not receiving any feedback/report after supervision".

"There is more improvement when you come to the issue of transparency compared to the previous years, for example these days we have a pharmaceutical dashboard whereby stock status reports are posted, so that all stakeholders in the pharmaceutical supply chain can be aware of the stock status in the country as a whole and individual health facilities around the country".

One informant at the regional level complained that they do not get feedback.

"We do not get feedback from our customers. There is also no such plan in place."

Sub theme 1.8 Budget Allocated to Health Facility

There is no policy or system in place which informed the head of the health centers, clinic or hospitals regarding the exact budget which allocated to pharmaceutical services**.**

Informants said:

"If we could know or be aware of exactly the money/budget allocated for pharmaceutical services to every level, staff could have the sense of responsibility, this will lead to order and use medicine wisely rather than what is being done currently. Medicine is being ordered without a clear knowledge of the budget allocated in their health facilities".

Sub theme 1.9. Lack of Proper preparation during Implementation of a Policy or Guidelines.

The informants also pointed out that most of the time there is/was no proper preparation before the implementation of a policy as illustrated in the following sub theme.

Informants had to say this: *"policy/guideline of testing for malaria by using mRDT to all suspected cases did not consider the storage capacity of the facility".*

"Integration of PMTCT programs with traditional services brings a lot of confusion as many health workers were not trained and also reports of mother to baby follow up is now filled with untrained health workers."

"Sometimes is confusing when it comes to the responsible person, between people employed through special programs or government and all are dealing with supply chain of mRDT and NVP syrup in the same capacity".

''OMRMD is very close to IHO but because of the policy and decision makers, we are sending our main order from CMS which is located more than 700km from Oshakati and do not allow to send our main order to OMRMD which is a few hundred meters from IHO. This makes unnecessary delay of services".

Sub theme 1.10. Doing double tasks (Task Shifting)

Nurses at the lower health facilities that are clinics are doing pharmacy job which they are not trained for. Informants had to say:

"The policy/SOP requires nurse incharge to do pharmacy job if the pharmacist or pharmacist assistant is not there, but in reality it is very difficult to perform two tasks at the same time.".

"Nurses have a lot of work to do relating to the nursing field, giving them another task (shifting task) will comprise the quality of services, and they will concentrate more on the task they know better".

Sub theme 1.11. Shortage of trained staff in Pharmaceutical Logistics.

Knowledge or availability of trained staff is very important in the pharmaceutical supply chain. Informants from health centers and clinics were dissatisfied with what they described as inadequate in-service training, guideline knowledge and shortage of pharmacy personnel, especially at the clinic level, which resulted in few suitably qualified staff to support mRDT and NVP syrup in PMTC implementation.

All informants echoed the same view that: *"Shortage of trained staff in the supply chain lead to overstock or understock especially at the lower level. Clinics are headed by registered nurses who are not well trained on the issue of supply chain of medicine".*

Nurses said *"We are not pharmacists or pharmacist assistant, but we are forcing ourselves to do pharmacy work without any training".*

Because of the workload and lack of training this is what informants said in the following sub theme:

"*We are ordering based on the ordering schedule which we received from OMRMD but the technique or what should we consider before ordering, we do not know."*

Sub theme 1.12. Delivery time.

This category/theme is very important as it illustrates on how reliable delivery of medicine can be a lifesaving. In today's modern pharmaceutical industry and increasing

globalization of Pharmaceutical Supply Chains, the supply chain often extends across multiple transportation routes and regulatory jurisdictions. These extended supply chains present specific challenges in terms of preserving the quality of the pharmaceutical product in-transit, delay of delivery and the increasing global risk of fake medicines entering the supply chain (81).

Informants had a different perception on the issue of transport as reported in sub theme below.

One of the informants at the management level said:

"According to Standard Operation Procedures (SOP) we are supposed to receive medication in 1 week after sending the order to CMS but because of the challenges in transport logistics, we are receiving medicines after 3 weeks or a month, this delay our services and you find us that all our safety stock will be consumed before new delivery".

But the informant was so impressed with delivery of medicines (NVP syrup and mRDT) within Oshana region *"OMRMD is now managed by more than 85% to deliver medicines on time in our health facilities according to SOP".*

Informants at the hospital level acknowledge that: *"there is some improvement in case of delivery lead time compares to the previous years, but still there are some hiccups here and there, which we don't know why".*

One of the informants *said "There is improvement in transport compared to the previous year, because the integration of program activity or vehicles and that of the governments. e.g. sharing of the vehicles to transport medication".*

Most of the informants from all levels of the supply chain were dissatisfied with the time of medicine delivery: *"Most of the time we are receiving the medicine out of prescribing time, this has delayed the services and sometime forced us to tell the patients to come the following day hoping that the medicines will be delivered the following day".*

"The issue of transport is a challenging issue, as you know that one driver is serving at least three clinics. It is very difficult to deliver on time. If other drivers are on leave or assign other duty, the issues of delivering pharmaceutical items on time become more difficult".

"There is no proper coordination between transport department and other departments dealing with pharmaceutical supply chain, this make some delays to deliver medicines".

Another concern regarding transportation is shortage of transport. One informant reported that: *"Regional medical store has responsibility to deliver to four regions, seven hospitals, 15 health care centres, 68 clinics, but has only one truck to do the deliveries at all those facilities."*

One of the informant added that *"A lot of bureaucracy almost contributing to the delay, you find that you need to follow a lot of procedures for the car to be released or to be assigned to that particular task. Because there is no dedicated car for pharmaceutical services only".*

4.3.4a Integration of Quantitative and Qualitative for Malaria Diagnostic Test Kit

Table 9. Link between quantitative and qualitative for mRDT.

	Quantitative		Link	Qualitative theme	
HF	**Sources**	**Factors/variable**		**Stock out**	**Sources**
OMRMD	SYSPRO,	Delivery lead time .P value < 0.05		-Transportation problem "Medicines including mRDT do not deliver on time."	Interview informants
	Oshana monthly weather report	Average temperature in °C P < 0.05		- "Many health facilities,especially clinics order more than what they actually consumed.	
	Oshana weather monthly report	Rainfall in mm		Consumption of mRDT increases during rain season "We are receiving more orders of mRDT during rainy season"	
HC		Average temperature °C		Delays in delivery mRDT	
		Rainfall in mm		-Improper orders	
Clinics	Stock card	Delivery lead time		" Most of the time we are receiving mRDT beyond the prescribed time"	
	Weather monthly report	Average temperature °C and rainfall in mm		Improper orders " This leads to over consumption and expired mRDT"	

Table 9, indicates the factors which are similar from both quantitative and qualitative findings, and those which are differ.

4.4a Development of Potential Model of Stock Level of mRDT

The following assumptions and notations were considered and adjusted in order to develop a potential model of stock levels of mRDT (105,106)

Assumptions

- Daily demand is stochastic, i.e. daily demand is independent of each other
- Inflation rate is non constant.
- Single supplier, manufactures and buyers are considered.
- Multiple period stochastic models.
- Health facilities use periodic review inventory policy.
- Transport cost from CMS to OMRMD and to all health facilities is constant.
- Production of pharmaceutical items is constant
- The production of items is greater than the demand.
- Storage capacity is the same to all health facilities.
- The service level is 98%
- Lead time for each level of the supply chain is constant
- CMS is only a single supplier of medicine to OMRMD
- OMRMD deliver the same lot size when the health facilities write requisition.
- Shortage of medicines is not allowed.

Notations

- $AMCrdt_{OMRMD}$ = Average monthly consumption of mRDT at OMRMD
- S_o=Stock on hand at order point.
- D_i= Monthly demand of mRDT at OMRMD.

- $Lrdt_{OMRMD}$ = Lead delivery time of mRDT at OMRMD in days.
- $rfrdt_{OMRMD}$ = Optimal reorder frequency of mRDT at OMRMD in days.
- $ssrdt_{OMRMD}$ =Optimal safety stock level of mRDT at OMRMD
- $zrdt_{OMRMD}$ = Probability of no stock out of NVP syrup at OMRMD during lead time.
- $\mu Drdt_{OMRMD}$ =Mean demand of mRDT at OMRMD
- σ^2DrdtOMRMD= Standard deviation demand of NVP syrup at OMRMD
- $\mu Lrdt_{OMRMD}$ =Mean delivery lead time of mRDT at OMRMD
- σ^2 LrdtOMRMD =Standard deviation delivery lead time of mRDT at OMRMD.
- $ROPrdt_{OMRMD}$ = Optimal maximum stock level of mRDT at OMRMD or reorder quantity/ point level of mRDT at OMRMD.

Formulation of Modeling Stock Level at OMRMD

The mathematical models to calculate the maximum order level (ROP) for mRDT involve the combination of two parts, namely cyclic inventory and safety inventory. Therefore, this is cyclic model or P model. The symbolic formula was as follows:

Cycle inventory = AMC ($Lrdt_{OMRMD}$ + $rfrdt_{OMRMD}$) and safety inventory is Zσ (AMC ($Lrdt_{OMRMD}$ + $rfrdt_{OMRMD}$).

Mean demand of mRDT at OMRMD is equal to the average monthly historic consumption of mRDT as shown below.

$AMCrdt_{OMRMD} = \mu Drdt_{OMRMD}$ ---------- (i).

Therefore $\mu Drdt_{OMRMD}(Lrdt_{OMRMD}+rfrdt_{OMRMD})$ and the safety stock level of NVP syrup at OMRMD($ssrdt_{OMRMD}$) is

$ssrdt_{OMRMD} = z\sigma\ (\mu Drdt_{OMRMD}\ (Lrdt_{OMRMD}+rfrdt_{OMRMD})$----------(ii)

The demand during lead time, plus review period DL $= \sum_{i=1}^{L+r} Di$ follows a normal distribution, whose expectation and variance can be calculated similarly as before

Expected demand (E)

$E[DL+rf] = E[\sum_{i=1}^{L+r} Di] = (rfrdtOMRMD + \mu LrdtOMRMD)\mu DrdtOMRMD$…(iii)

Variance (V)

$V[DL+rf] = V[\sum_{i=1}^{L+r} Di] = (rfrdtOMRMD + \mu LrdtOMRMD)\sigma^2 DrdtOMRMD + \sigma^2 L\mu^2 DrdtOMRMD$…….(iv)

$ROPrdt_{OMRMD}$ = (iii) + (iv)

$ROPrdt_{OMRMD} = \mu Drdt_{OMRMD}(\mu Lnvp_{OMRMD} + rfrdt_{OMRMD}) + z\alpha\sqrt{(\mu LrdtOMRMD + rfrdtOMRMD)\sigma^2 DrdtOMRMD + \mu 2\, D\sigma^2 LrdtOMRMD}$ ----------(v)

To prevent a stock out of mRDT during the lead time, the service level (1- α) should be 98%. According to Namibia Essential Medicine List (NEMLIST) NVP syrup is among the vital items, in which the service level should be 95-98% (63). The higher the z score the less the item will be out of stock. Therefore, to achieve service level of 98%, z value or service factor need to be 2.05.

Therefore, $ROPrdt_{OMRMD}$ = μDrdtOMRMD ($\mu Lrdt_{OMRMD}$ + $rfrdt_{OMRMD}$) + 2.05 $\sqrt{(\mu LrdtOMRMD + rfrdtOMRMD)\sigma 2\, DrdtOMRMD + \mu 2\, D\sigma 2\, LrdtOMRMD}$ …….(vi)

The quantity to order ($ROPnvp_{OMRMD}$) is replenishment level minus quantity on hand.

$ROPrdt_{OMRMD}$ = $ROPrdt_{OMRMD}$ - S_o----------(vi)

4.4.1a Delivery lead time of mRDT at OMRMD

The following is the table presenting the frequency of delivery lead time of mRDT from CMS to OMRMD**.**

In table 10 expected times is the expected replenishment time of mRDT and actual replenishment time is the real time it took to replenish each order in the data provided (2012-2016). Positive numbers are the number of days over the expected time and negative numbers mean that the delivery arrived earlier than the expected time.

Note. Cm is the consumption of mRDT at OMRMD

Table 10. Replenishment time for mRDT at OMRMD.

Quarter	Actual replenishment time (days)	Expected replenishment time (days)	Variance (σL_m) Actual replenishment-expected)	Outcome (Consumption) C_m
2012Q1	44	30	14	5008
2012Q2	42	30	12	4672
2012Q3	23	30	-7	7575
2012Q4	48	30	18	4202.
2013Q1	49	30	19	5513
2013Q2	49	30	19	5132
2013Q3	49	30	19	8303
2013Q4	22	30	-8	4596
2014Q1	30	30	0	6019
2014Q2	14	30	-16	5592
2014Q3	72	30	42	9031
2014Q4	79	30	49	4990
2015Q1	20	30	-10	6524
2015Q2	45	30	15	6052
2015Q3	49	30	19	9758
2015Q4	48	30	18	5384
2016Q1	31	30	1	7029
2016Q2	47	30	17	6511
2016Q3	67	30	37	10485
2016Q4	46	30	16	5778
			274	128155

Therefore, the total variance in a quarter / number of observations=274/20 =14 days in a quarter which is equivalent to 3 months. For a month =14/3 = 5 days, therefore replenishment time is 10 +5= 15. .According to SOP(65) the replenishment time is 2

weeks, which is equivalent to 10 working days. 10+5=15 days. Hence the standard deviation of lead time of mRDT at OMRMD ($\sigma LTrdt_{OMRMD}$) = 15 days. Fifteen(15) days signifies the average amount of time it takes to restock, after taking into account the variability in the actual time that orders have been received in the past. This is also the amount of time that safety stock will have to hold at OMRMD over until new stock of mRDT arrives.

4.4.2a Optimal Reorder Point of mRDT at OMRMD (ROPrdtOMRMD)

For the demand average of mRDT at OMRMD ($\mu Drdt_{OMRMD}$)=AMC_m .Therefore AMC_m = Total consumption/total months =128155/60 = 2135 tests of mRDT = µDrdt. For the daily demand of mRDT at OMRMD =128155/ 1200 = 107 tests = 4P/25. The safety stock ($ssrdt_{OMRMD}$) is 4 x 15 = 60 P/25 of mRDT (Daily consumption/demand). But for the safety stock level of mRDT at OMRMD($ssrdt_{OMRMD}$) we need to consider the service level(z). The service level = 98%. From the normal distribution chart, the service factor for the service level of 98% = 2.05. The $SSrdt_{OMRMD} = z \times \Sigma LTrdt_{OMRMD} \times \mu Drdt_{OMRMD}$ = 2.05 x4x15 = 123 P/25 of mRDT. Safety stock for mRDT at OMRMD =123 P/25

$ROPrdt_{OMRMD} = \mu Drdt_{OMRMD} \text{ x } \Sigma LTrdt_{OMRMD} + SSrdt_{OMRMD}$

=4 x 15 +123 = 183 P/25 of mRDT.

4.4.3a Optimal Reorder Frequency of mRDT at OMRMD

= Total orders required / Orders requested by OMRMD = 60/34=approximately 7 weeks.

4.4.4a Optimal Models of mRDT at HCs.

The following assumptions and notations were considered and adjusted in order to develop an optimal mathematical model of mRDT at Health centers (HC) (105,106)

Assumptions

- Daily demand is stochastic, i.e daily demand is independent of each other
- Inflation rate is non constant.
- Single supplier, manufactures and buyers are considered.
- Multiple period stochastic models.
- Health facilities use periodic review inventory policy.
- Transport cost from OMRMD to all health centres is constant.
- Production of pharmaceutical items is constant
- The production of items is greater than the demand.
- Storage capacity is the same to all health centres.
- The service level is 96%
- Lead time for each level of the supply chain is different
- OMRMD is only a single supplier of medicine to health centers
- OMRMD deliver the same lot size when the health facilities write requestion.
- Shortage of medicines is not allowed.

Notations

- $AMCm_{HC}$ = Average monthly consumption of mRDT at HC
- S_o=Stock on hand at order point.
- D_i= Monthly demand of mRDT at HC.
- Lm_{HC} = Lead delivery time of mRDT at HC in days.
- rfm_{HC} = Optimal reorder frequency of mRDT at HC in days.
- ssm_{HC} =Optimal safety stock level of mRDT at HC
- zm_{HC} = Probability of no stock out of mRDT at HC during lead time.
- μDm_{HC} =Mean demand of mRDT at HC
- σ^2DmHC= Standard deviation demand of mRDT at HC
- μLm_{HC} =Mean delivery lead time of mRDT at HC
- σ^2 LnvpHC =Standard deviation delivery lead time of NVP syrup at HC.
- $ROPm_{HC}$ = Optimal maximum stock level of mRDT at HC or reorder quantity/ point level of mRDT at HC.

Formulation of Modeling Stock Level

The mathematical models to calculate the maximum order level (ROP) for mRDT involve the combination of two parts, namely cyclic inventory and safety inventory. Therefore, this is cyclic model or P model. The symbolic formula was as follows:

Cycle inventory = AMC (Lm_{HC} + rfm_{HC}) and safety inventory is Zσ (AMC (Lm_{HC} + rfm_{HC}).

Mean demand of mRDT at HC is equal to the average monthly historic consumption of Mrdt as shown below.

$AMCm_{HC} = \mu Dm_{HC}$ ---------- (i).

Therefore $\mu Dm_{HC}(Lm_{HC}+rfm_{HC})$ and the safety stock level of NVP syrup at HC(ssm_{HC}) is

$ssm_{HC} = z\sigma (\mu Dm_{HC} (Lm_{HC}+rfm_{HC})$----------(ii)

The demand during lead time, plus review period DL $= \sum_{i=1}^{L+r} Di$ follows a normal distribution, whose expectation and variance can be calculated similarly as before

Expected demand (E)

$E[DL+rf] = E[\sum_{i=1}^{L+r} Di] = (rfmHC + \mu LmHC)\mu DmHC$…(iii)

Variance (V)

$V[DL+rf] = V[\sum_{i=1}^{L+r} Di] = (rfmHC + \mu LmHC)\sigma^2 DmHC + \sigma^2 L\mu^2 DmHC$…….(iv)

$ROPm_{HC}$ = (iii) + (iv)

$ROPm_{HC} = \mu Dm_{HC}(\mu Lm_{HC} + rfm_{HC}) + z\alpha\sqrt{(\mu LmHC + rfmHC)\sigma^2 DmHC + \mu 2 D\sigma^2 LmHC}$ ---------(v)

To prevent a stock out of mRDT at HC during the lead time, the service level (1- α) should be 96%. According to Namibia Essential Medicine List (NEMLIST) NVP syrup is among the vital items, in which the service level should be 95-98% (63). The higher the z score the less the item will be out of stock. Therefore, to achieve service level of 96%, z value or service factor need to be 1.96.

Therefore, $ROPm_{HC}$ = μDm_{HC} (μLm_{HC} + rfm_{HC}) + $1.96\sqrt{(\mu LmHC + rfmHC)\sigma 2\, DmHC + \mu 2\, D\sigma 2\, LmHC}$ …….(vi)

The quantity to order ($ROPm_{HC}$) is replenishment level minus quantity on hand.

$ROPm_{HC} = ROPm_{HC} - S_o$----------(vi)

4.4.5a Delivery Lead Time of mRDT at HCs

The expected time is the expected replenishment time of mRDT and actual replenishment time is the real time it took to replenish each order in the data provided (2012-2016). Positive numbers are the number of days over the expected time and negative numbers mean that the delivery arrived earlier than the expected time. With this information, the researcher was able to find the standard deviation in lead time hence safety stock.

Table 11. Replenishment of mRDT at HCs in Oshana region.

Quarter	Actual replenishment time (days)	Expected replenishment time (days)	Variance	Outcome consumption (C_{mh}
2012Q1	1	15	-14	255
2012Q2	8	15	-7	279
2012Q3	11	15	-4	453
2012Q4	17	15	2	911
2013Q1	23	15	8	1139
2013Q2	26	15	11	798
2013Q3	28	15	13	1029
2013Q4	36	15	21	1787
2014Q1	41	15	26	2022
2014Q2	43	15	28	1317
2014Q3	48	15	33	1604
2014Q4	48	15	33	2664
2015Q1	13	15	-2	2906
2015Q2	16	15	1	1836
2015Q3	20	15	5	2178
2015Q4	40	15	25	3539
2016Q1	33	15	18	3789
2016Q2	30	15	15	2355
2016Q3	24	15	9	2753
2016Q4	37	15	16	4416
	Total		237	38030

Note that in table 11, C_{mh} represent consumption of mRDT.

Total variance in a quarter / number of observations =237/20=12 days in a quarter which is equivalent to 3 months. For a month =16/3 = 5 approximately is 4 days in a month,

therefore there is an extra of five days. The replenishment time is 1 week, which is equivalent to 5 working days. 5+ 4 = 9 days. Therefore, there is an extra of 4 days.

Hence the standard deviation of lead time of mRDT at HC (σLTm_{HC})=9 days. Fifteen (15) days signifies the average amount of time it takes to restock, after taking into account the variability in the actual time that orders have been received in the past. This is also the amount of time that safety stock will have to hold at health centers over until new mRDT arrives.

4.4.6a Optimal Reorder Point of mRDT at HCs.(ROPmHC)

For the demand average (μDm_{HC}) = $AMCm_{HC}$ therefore $AMCm_{HC}$ = Total consumption/total months = 38030/60= 633 test of malaria = μDm_{HC}. For the daily demand of mRDT at HCs =38030/1200 = 32 tests which equivalent to 1 P/25 of mRDT. The safety stock of mRDT at HCs (ssm_{HC}) is 1 x 9 = 9 P/25 of mRDT (Daily consumption/demand).

But for the safety stock level of mRDT at the HCs needed to consider the service level of mRDT at the clinic (zm_{HC}). The service level = 96%. From the normal distribution chart, the service factor for the service level of 96% = 1.75. The $ssm_{HC} = zm_{HC} \times \sigma LTm_{HC} \times \mu Dm_{HC}$ =1.75 x 9 x 1 = 16 P/25 of mRDT. Safety stock for mRDT at HCs =16 P/25.

Optimal reorder point = daily demand (μDm_{HC}) x lead time($\Sigma LT\ m_{HC}$) + safety stock (ss m_{HC}).

= 1 x 9+16 = 25 P/25

ROP m_{HC} = 25 P/25.

4.4.7a Optimal Reorder Frequency

= Total order required from 2012-2016/ order requested from 2012-2016

=60/56= approximately 4 weeks.

4.4.8a Optimal Model of mRDT at the clinics

The following assumptions and notations were considered and adjusted in order to develop an optimal mathematical model of mRDT at the clinics (105,106)

Assumptions

- Daily demand is stochastic, i.e daily demand is independent of each other
- Inflation rate is non constant.
- Single supplier, manufactures and buyers are considered.
- Multiple period stochastic models.
- Health facilities use periodic review inventory policy.
- Transport cost from OMRMD to all health facilities is constant.
- Production of pharmaceutical items is constant
- The production of items is greater than the demand.
- Storage capacity is the same at all health clinics.
- The service level is 90%
- Lead time for each level of the supply chain is different
- OMRMD is only a single supplier of medicine to health centers
- OMRMD deliver the same lot size when the health facilities write requestion.
- Shortage of medicines is not allowed.

Notations

- $AMCnvp_C$ = Average monthly consumption of mRDT at clinics
- S_o=Stock on hand at order point.
- D_i= Monthly demand of mRDT at clinics.
- L_{MC} = Lead delivery time of mRDT at clinics in days.
- rf_{MC} = Optimal reorder frequency of mRDT at clinics in days.
- ss_{MC} =Optimal safety stock level of mRDT at clinics
- z_{MC} = Probability of no stock out of mRDT at clinics during lead time.
- μD_{MC} =Mean demand of mRDT at clinics
- σ^2DMC= Standard deviation demand of mRDT at clinics
- μL_{MC} =Mean delivery lead time of mRDT at clinics
- σ^2 LMC =Standard deviation delivery lead time of mRDT at clinics.
- ROP_{MC} = Optimal maximum stock level of mRDT at clinics or reorder quantity/ point level of mRDT at clinics.

Formulation of model of stock levels

The mathematical models to calculate the maximum order level (ROP) for mRDT involve the combination of two parts, namely cyclic inventory and safety inventory. Therefore, this is cyclic model or P model. The symbolic formula was as follows:

Cycle inventory = AMC (L_{MC} + rf_{MC}) and safety inventory is Zσ (AMC (L_{MC} + rf_{MC}).

Mean demand of mRDT at the clinics is equal to the average monthly historic consumption of mRDT as shown below.

$AMC_{MC} = \mu D_{MC}$ ---------- (i).

Therefore $\mu D_{MC}(L_{MC}+rf_{MC})$ and the safety stock level of mRDT at clinics(ss_{MC}) is

$ss_{MC} = z\sigma\ (\mu D_{MC}\ (L_{MC}+rf_{MC})$----------(ii)

The demand during lead time, plus review period DL $= \sum_{i=1}^{L+r} Di$ follows a normal distribution, whose expectation and variance can be calculated similarly as before

Expected demand (E)

$E[DL+rf] = E[\sum_{i=1}^{L+r} Di] = (rfMC + \mu LMC)\mu DMC$…(iii)

Variance (V)

$V[DL+rf] = V[\sum_{i=1}^{L+r} Di] = (rfMC + \mu LMC)\sigma^2 DMC + \sigma^2 L\mu^2 DMC$…….(iv)

$ROPnvp_C$ = (iii) + (iv)

$ROP_{MC} = \mu D_{MC}(\mu L_{MC} + rf_{MC}) + z\alpha\sqrt{(\mu LMC\ +\ rfMC\ )\sigma^2\ DMC\ +\ \mu 2\ D\sigma^2\ LMC}$ --------(v)

To prevent a stock out of mRDT at the clinics during the lead time, the service level (1-α) should be 96%. According to Namibia Essential Medicine List (NEMLIST) mRDT is among the vital items, in which the service level should be 95-98% (63). The higher the z score the less the item will be out of stock. Therefore, to achieve service level of 96%, z value or service factor need to be 1.96.

Therefore, $ROP_{MC} = \mu D_{MC}\ (\mu L_{MC} + rf_{MC}) + 2.05\sqrt{(\mu LMC\ +\ rfMC\ )\sigma 2\ DMC\ +\ \mu 2\ D\sigma 2\ LMC}$ …….(vi)

The quantity to order ($ROPnvp_C$) is replenishment level minus quantity on hand.

$ROP_{MC} = ROP_{MC} - S_o$----------(vi)

4.4.9a Delivery Lead Time of mRDT at Clinics

The expected time is the expected replenishment time of mRDT and actual replenishment time is the real time it took to replenish each order in the data provided (2012-2016). Positive numbers are the number of days over the expected time and negative numbers mean that the delivery arrived earlier than the expected time. With this information, the researcher was able to find the standard deviation in lead time hence safety stock. C_{mc} represents consumption of mRDT at the clinics.

Table 12. Replenishment of mRDT at clinics in Oshana region

Quarter	Actual replenishment time(days) in a quarter	Expected replenishment time(days) in a quarter	Variance	Outcome consumption C_{mc}
2012Q1	0	15	-15	93
2012Q2	2	15	-13	2
2012Q3	11	15	-4	43
2012Q4	15	15	0	145
2013Q1	22	15	7	270
2013Q2	28	15	13	217
2013Q3	33	15	18	221
2013Q4	39	15	24	441
2014Q1	44	15	29	634
2014Q2	32	15	17	354
2014Q3	23	15	8	399
2014Q4	41	15	26	736
2015Q1	37	15	22	998
2015Q2	18	15	3	655
2015Q3	29	15	14	577
2015Q4	36	15	21	1032
2016Q1	40	15	25	1362
2016Q2	51	15	36	874
2016Q3	23	15	8	754
2016Q4	27	15	12	1328
	Total		251	11135

Total variance in a quarter / number of observations = 251/20 = 13 days in a quarter which is equivalent to 3 months. For a month =13/3 = 7. Approximately is 4 days in a month, therefore there is an extra of 4 days. The replenishment time is 1 week, which is equivalent to 5 working days. 5+4=9 days. Therefore, there is an extra of 4 days.

Hence the standard deviation of lead time of mRDT at clinics (σLT_{MC}) = 4 days. 4 days signifies the average amount of time it takes to restock, after taking into account the variability in the actual time that orders have been received in the past. This is also the amount of time that safety stock will have to hold at clinics over until new mRDT arrives.

For the demand average **(**μD_{MC})=AMC_{MC} therefore AMC_{MC} =Total consumption/total months=11135/60= 186 of mRDT, which is 7 P/25 = μD_{MC}. For the daily demand of mRDT at clinics =11135/ 1200 = 9 tests of mRDT. The safety stock of mRDT at clinics (ss_{MC}) is 9 x 9 = 81 tests, equivalent to 3P/25 of mRDT. (Daily consumption/demand).

But for the safety stock level of mRDT at the clinics needs to consider the service level (z). The service level = 96%. From the normal distribution chart, the service factor for the service level of 96% =1.75. The ss_{MC}= z $\times \sigma LT_{MC} \times \mu D_{MC}$ =1.75 x 9 x 9 = 142 = 6 P/25 of mRDT.as a safety stock

4.4.10a Optimal Reorde Level of mRDT at Clinics. (ROPMC)

ROP_{MC} = Daily demand x lead time + safety stock.

= μD_{MC} x σLT_{MC} +ss_{MC} = 9tests x 9 +6 = 9 P/25.

4.4.11a Optimal Reorder Frequency of mRDT at the Clinics

Reorder frequency= 4 weeks

4.5a.Simulation of the Potential Model of mRDT

The optimal models of stock level of mRDT were simulated in order to evaluate and validate the model based on two variables, which are average demand and lead time.

Table 13. Simulated demands of mRDT **.**

Category	Month	Monthly demand	Probability	Cumulative probability	Random number interval	Random number	Demand
OMRMD	Q1	7533	0.236	0.236	0 - 235	637	11212
	Q2	6970	0.219	0.455	236 - 454	999	6172
	Q3	11212	0.352	0.807	455 - 806	605	11212
	Q4	6172	0.193	1	807 - 999	324	6970
						Total	**35566**
						Avg daily demand	**99**
HCs	Q1	4672	0.289	0.289	0 - 288	547	3328
	Q2	2873	0.178	0.467	289 - 466	403	2873
	Q3	3328	0.206	0.673	467 - 672	58	4672
	Q4	5292	0.327	1	673 - 999	642	3328
						Total	**14201**
						Avg daily demand	**39**
Clinics	Q1	1726	0.321	0.321	0 - 320	832	1624
	Q2	1093	0.203	0.524	321 - 523	714	1624
	Q3	932	0.173	0.697	524 - 696	752	1624
	Q4	1624	0.302	1	696- 999	258	1726
						Total	**6598**
						Avg daily demand	**18**

Table 13, shows the average demand of mRDT at different facilities in Oshana region.

Table 14. Simulated lead time of mRDT.

Category	Month	Lead time (days)	Probability	Cumulative probability	Random number interval	Random number	Lead time
OMRMD	1	7	0.11	0.11	0 - 10	7	7
	2	18	0.29	0.40	11 - 39	65	29
	3	9	0.14	0.54	40 - 53	54	29
	4	29	0.46	1.00	54 - 99	38	18
						Total	83
						Avg lead time	21
HCs	1	3	0.12	0.12	0 - 11	8	3
	2	8	0.31	0.43	12 - 42	38	8
	3	3	0.12	0.55	43 - 54	81	12
	4	12	0.46	1.00	55 - 99	33	8
						Total	31
						Avg lead time	8
Clinics	1	6	0.31	0.31	0 - 30	39	8
	2	8	0.42	0.73	31 - 72	90	4
	3	4	0.21	0.94	73 - 93	57	8
	4	1	0.05	0.99	94 - 98	53	8
				1.00	99	Total	28
						Avg lead time	7

4.5.1a Validation of the potential model of mRDT

The models were validated by comparing developed model results and the simulated results

* ROP_{MOMRMD} = 99 tests = 4 P/25 x 21 + 123 = 207 P/25 of mRDT (Simulation)

ROP_{MOMRMD} = 183 P/25 of mRDT (Model)

Validation accuracy = 183/207 = 88.4 % predictive accuracy

* ROP_{MH} = 39 tests = 2 P/25 x 8 + 16 = 32 P/25 (Simulation)

ROP_{MH} = 25 P/25 (Model)

Validation accuracy = 25/32 = 78.1 % Predictive accuracy

* ROP_{MC} = 9 tests x 7 + 6 = 9 P/25 (Simulation)

ROP_{MC} = 9 P/25 (Model)

Validation accuracy = 9/9 = 100 % Predictive accuracy

4.5.2a Malaria Model Presentation

Figure 12. Malaria test kit model presentation.

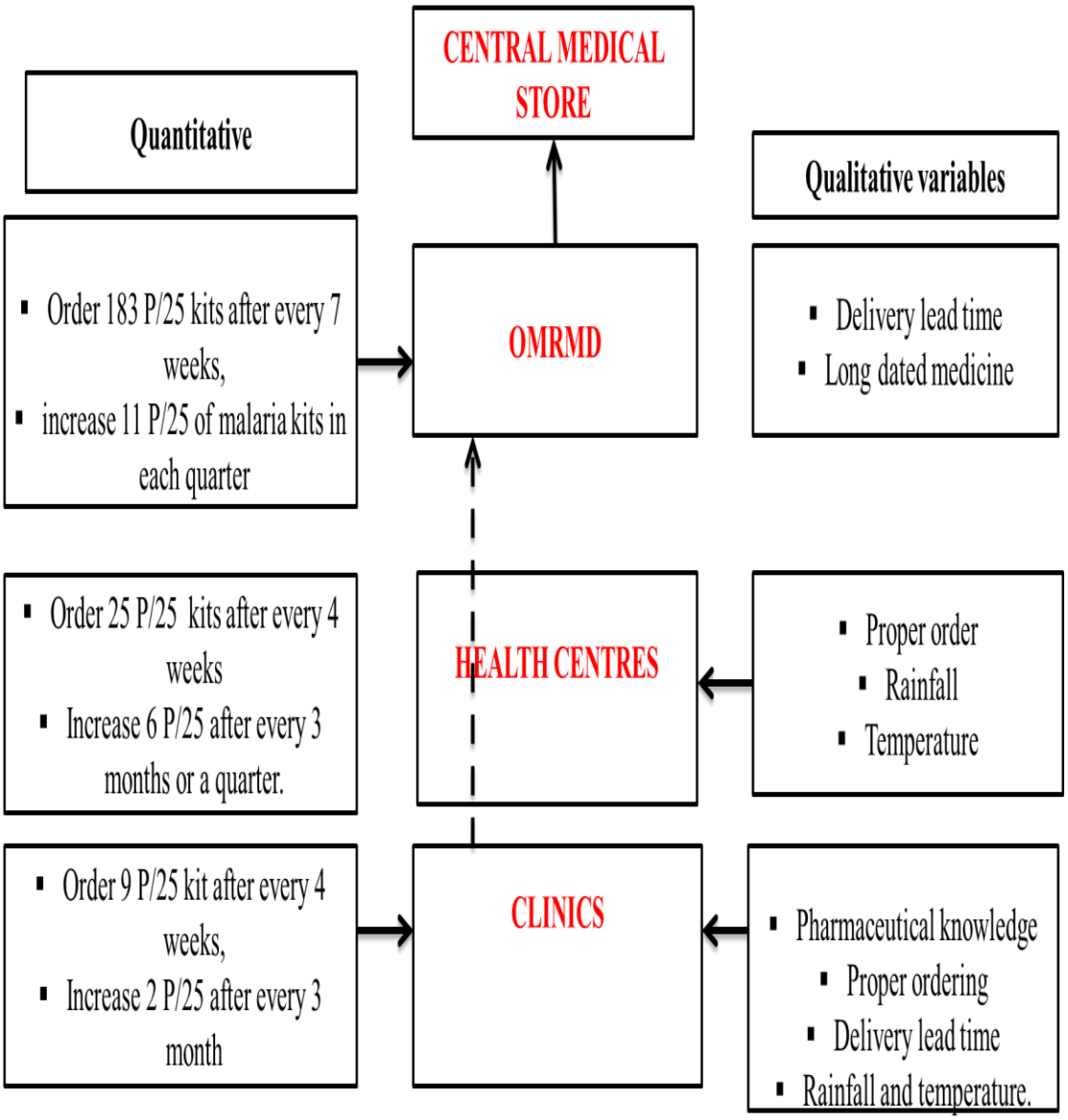


Figure 12, represents how public health facilities should order malaria diagnostic test kit.

PART B: Results for Nevirapine Syrup (NVP syrup)

4.1b Introduction

Part B, of chapter four presents quantitative and qualitative findings of NVP syrup. The findings consist of time series in which different patterns were identified and consumption rates calculated in quarter. Quantitatively, factors which are statistically significant associated with stock out were triangulated with qualitative factors which are linked to stock out. The qualitative factors were obtained from sub themes. Predictors of stock out were used as a basis to develop a stock level model of NVP syrup. The potential model developed was verified validated and illustrate how well the model depicts the condition of the real world. This was done by means of simulation

4.2b Consumption rates and Trend of NVP syrup

4.2.1b Consumption Rates of NVP Syrup at OMRMD

Descriptive statistics of consumption of NVP syrup at OMRMD are shown in figure 12. The figure shows there is no consistent trend in consumption of NVP syrup at OMRMD in Oshana region. The trend fluctuates from quarter to quarter with cyclic movement, though seasonality appears in every fourth quarter of the year. Hence, in the trend, variance is not constant. Consumption in the series appears to wander up and down slowly. There was a very sharp increase in consumption of NVP syrup in the third quarter of 2016. The trend showed there is a positive secular trend with cyclic movement, which is defined by the equation $y = 32x + 255$.

The centered, moving average showed that, from 2012 up to the third or fourth quarter of 2016, the consumption of NVP syrup was relatively constant until it drastically increased.

Note. CMA (4) in figure 12 represented the Central Moving Average in four periods..

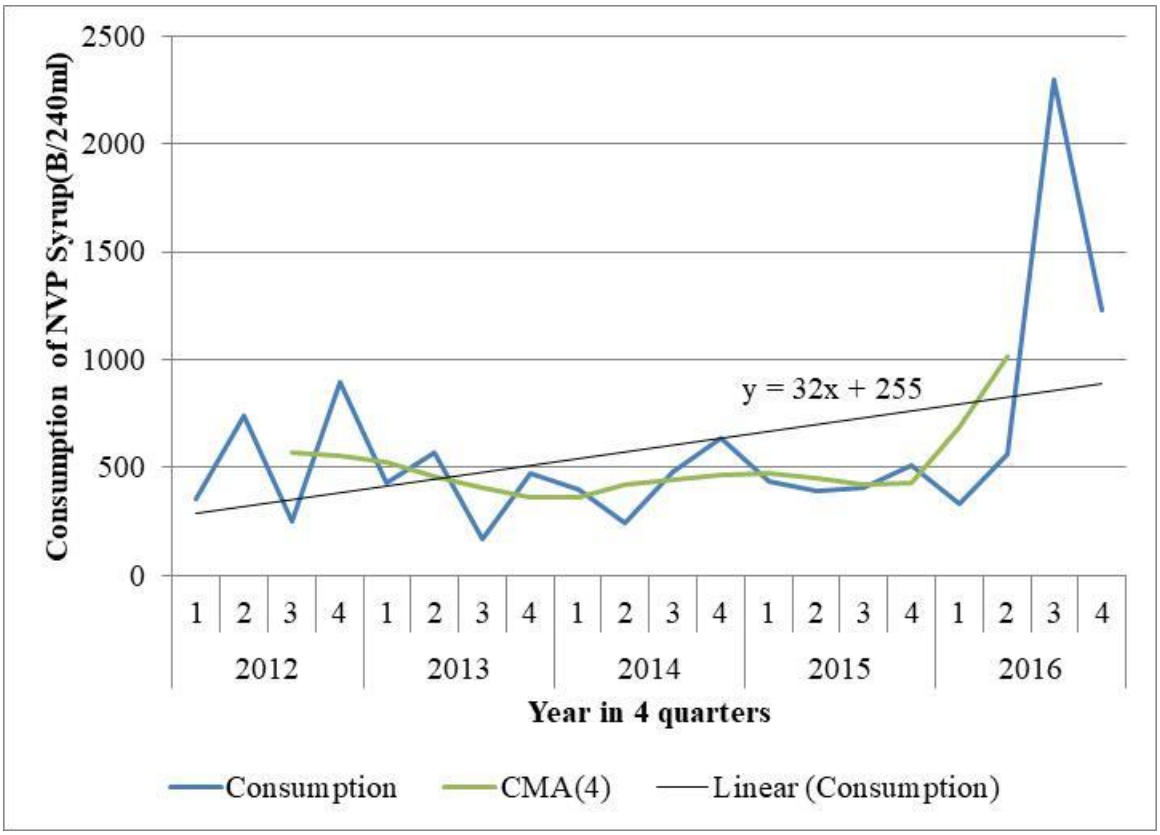


Figure 12. Time series trend of NVP syrup consumption and centered moving average (baseline) in quarterly basis.

The main objective of the analysis was to determine the average monthly consumption (AMC), using a moving average to smooth out variations in the consumption, and simple linear-regression model in SPSS to predict (or forecast) consumption of NVP syrup beyond 2016.

Table 15 presented a time-series analysis of NVP syrup at OMRMD. In the table, CMA(4) was used to smooth the variation of consumption data. The classic multiplicative model ($Y_t=S_t \times I_t \times T_t$) was used to derive seasonal and irregular components, while a simple linear regression was used to forecast and assess the fitness.

Year 2, 3, 4, 5, 6, 7 and 8 represent 2012, 2013, 2014, 2015, 2016, 2017 and 2018. The red figures (values) indicate consumption of NVP syrup forecasted for the period of 2017-2018.

Note: MA(4) is a moving average of four periods. CMA(4) is a centered, moving average of four periods. S_t is the seasonal trend, I_t is irregular trends, C_p is the consumption of Nevirapine syrup at OMRMD in over a quarter and T_t is the time trend

Table 15 Quarter year consumption of NVP syrup and forecasting at OMRMD

		Y_t		Baseline	Y_t/CMA		Y_t/S_t	T_t	
t		C_p	MA(4)	CMA(4)	S_t, I_t	S_t	Deseasonalize		Forecasting
1	2012Q1	354				0.83	426	302	251
2	2012Q2	738				0.81	911	339	275
3	2012Q3	253	560.75	569.62	0.44	0.72	351	377	271
4	2012Q4	898	578.5	556.87	1.61	1.37	655	414	567
5	2013Q1	425	535.25	524.25	0.81	0.83	512	451	374
6	2013Q2	565	513.25	460.12	1.23	0.81	697	489	396
7	2013Q3	165	407	403.5	0.41	0.72	229	526	379
8	2013Q4	473	400	359.37	1.32	1.37	345	563	771
9	2014Q1	397	318.75	357.62	1.11	0.83	478	601	499
10	2014Q2	240	396.5	417.25	0.57	0.81	296	638	516
11	2014Q3	476	438	442.37	1.08	0.72	661	676	487
12	2014Q4	639	446.75	465.62	1.37	1.37	466	713	977
13	2015Q1	432	484.5	475.75	0.91	0.83	520	750	622
14	2015Q2	391	467	450.62	0.87	0.81	482	788	638
15	2015Q3	406	434.25	421.5	0.96	0.72	563	825	594
16	2015Q4	508	408.75	429.9	1.18	1.37	370	863	1182
17	2016Q1	330	451	687.5	0.48	0.83	397	900	747
18	2016Q2	560	924	1014.6	0.55	0.81	691	937	759
19	2016Q3	2298	1105.3			0.72	3191	975	702
20	2016Q4	1233				1.37	899	1012	1386
21	2017Q1					0.83		1049	871
22	2017Q2					0.81		1087	880
23	2017Q3					0.72		1124	809
24	2017Q4					1.37		1161	1591

Table 15 indicated that in quarter 1, 2 and 3 the consumption of NVP syrup at OMRMD is below the baseline by 17%, 19% and 28% respectively and quarter 4 is above the baseline by 37%.

4.2.2b Consumption trend of NVP syrup at HCs

Figure 13, show that there is variation in trend in consumption of NVP syrup at HCs in Oshana region. The trend indicated both cyclic and seasonal characteristics. Consumption of NVP syrup is decreasing most of the time in March of every year. The series appears to wander up and down at the mean. No any outliers. The graph showed that, there is a slight positive secular trend with seasonality and cyclic.

Note C_{ph} is consumption of NVP syrup at health centers.

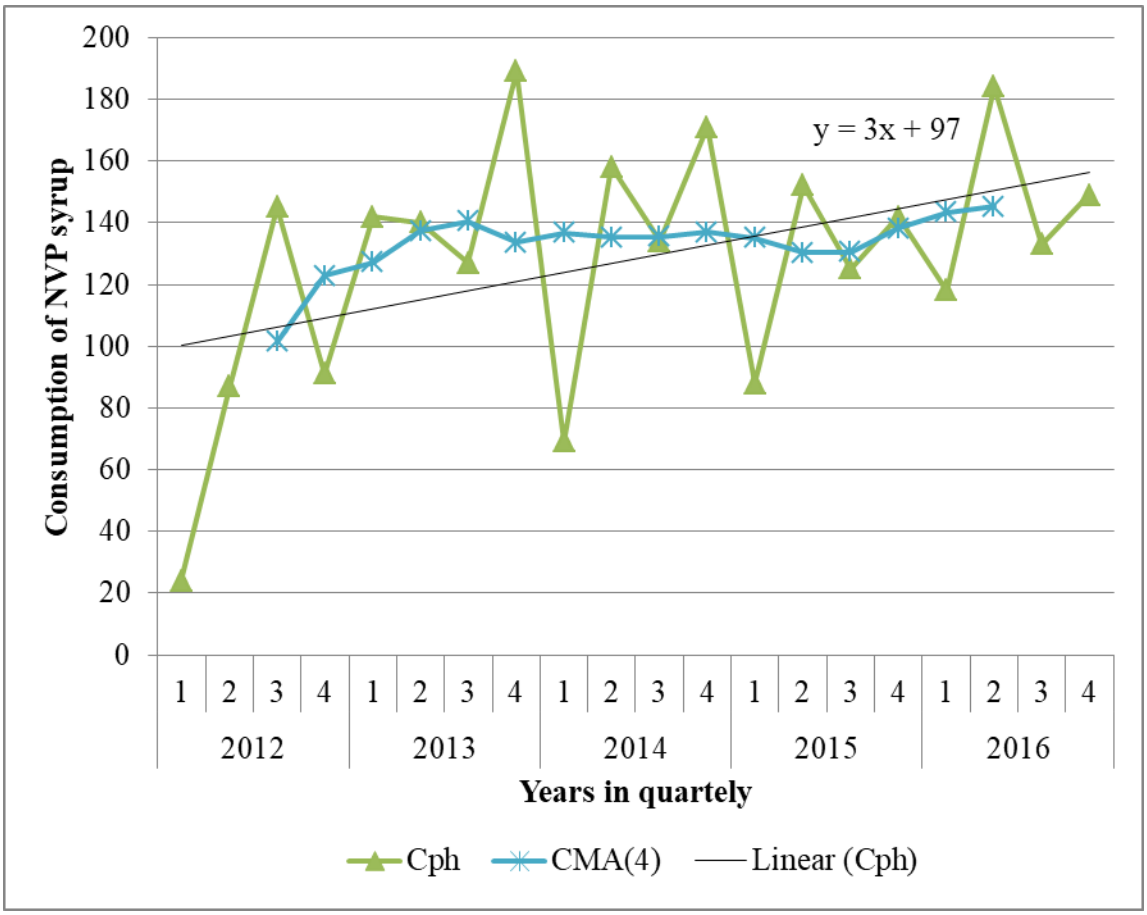


Figure 13. Time series trend of NVP syrup consumption and centered moving average (baseline) in quarterly basis at HCs

The linear line above indicates that there is a positive secular trend of consumption of NVP syrup at HCs. Note that C_{ph} means consumption of nevirapine syrup at health centres. CMA (4) Central Moving Average in the quarter.

This time series analysis combined the consumption of all health centres in Oshana region. Consumption of NVP syrup at health centers (HCs) was based on the issue of NVP syrup to the patients (babies born with HIV positive mothers). Below is the table 4.2 for time series analysis of NVP syrup at OMRMD. As other table above, CMA(4) was used to smooth the variation of consumption data. Classical multiplicative model (

$Y_t=S_t$ x I_t x T_t) was used to get seasonal and irregular components and simple linear regression was used to calculate the forecasting and assess the fitness. The red numbers (values) indicate consumption of NVP syrup forecasted for the period of 2017-2018.

Note: MA (4) is moving average of four periods, CMA (4) is centered moving average of four periods. S_t is seasonal trend, I_t is irregular trends, C_{ph} is consumption of Nevirapine syrup at health centers in quarterly and T_t is time trend. The table in S_t column shows that in quarter one of each year, 23% of the consumptionis below the baseline. Quarter two, three and four are above the baseline, which is 16%, 7% and 11% respectively.

Table 16 Quarterly consumption of NVP syrup and forecasting at health centers

		Y_t			Y_t/CMA		Y_t/S_t	T_t	
t	Year	C_{ph}	MA(4)	CMA(4)	S_t, I_t	S_t	Deseasonalize		Forecasting
1	2012Q1	24				0.77	30	99.16	77
2	2012Q2	87				1.16	75	101.72	118
3	2012Q3	145	86.75	101.5	1.43	1.07	135	104.29	112
4	2012Q4	91	116.25	122.9	0.74	1.11	81	106.86	119
5	2013Q1	142	129.5	127.25	1.12	0.77	183	109.43	85
6	2013Q2	140	125	137.25	1.02	1.16	120	111.99	130
7	2013Q3	127	149.5	140.37	0.91	1.07	118	114.56	123
8	2013Q4	189	131.25	133.5	1.42	1.11	170	117.13	130
9	2014Q1	69	135.75	136.62	0.5	0.77	89	119.70	93
10	2014Q2	158	137.5	135.25	1.17	1.16	136	122.27	142
11	2014Q3	134	133	135.37	0.99	1.07	125	124.83	134
12	2014Q4	171	137.75	137	1.25	1.11	154	127.40	141
13	2015Q1	88	136.25	135.12	0.65	0.77	113	129.97	101
14	2015Q2	152	134	130.37	1.17	1.16	131	132.54	153
15	2015Q3	125	126.75	130.5	0.95	1.07	116	135.10	145
16	2015Q4	142	134.25	138.25	1.03	1.11	127	137.67	153
17	2016Q1	118	142.25	143.25	0.83	0.77	152	140.24	109
18	2016Q2	184	144.25	145.12	1.27	1.16	158	142.81	165
19	2016Q3	133	146			1.07	124	145.37	156
20	2016Q4	149				1.11	134	147.94	164
21	2017Q1					0.77		150.51	117
22	2017Q2					1.16		153.08	177
23	2017Q3					1.07		155.64	167
24	2017Q4					1.11		158.21	176

4.2.3b Consumption rate of NVP syrup at the clinics

Figure 14 is the graph which showed the trend of consumption of NVP syrup at the clinics with centered moving average. It showed that there is variation in trend in consumption of NVP syrup at clinics in Oshana region. The trend indicates cyclic characteristics.. The series as the previous ones appear to wander up and down. No any outliers. The graph shows that, there is a positive secular trend with the cyclic. The positive trend is shown with the equation y = 2x + 15. Note C_{pc} is consumption of NVP syrup at clinics.

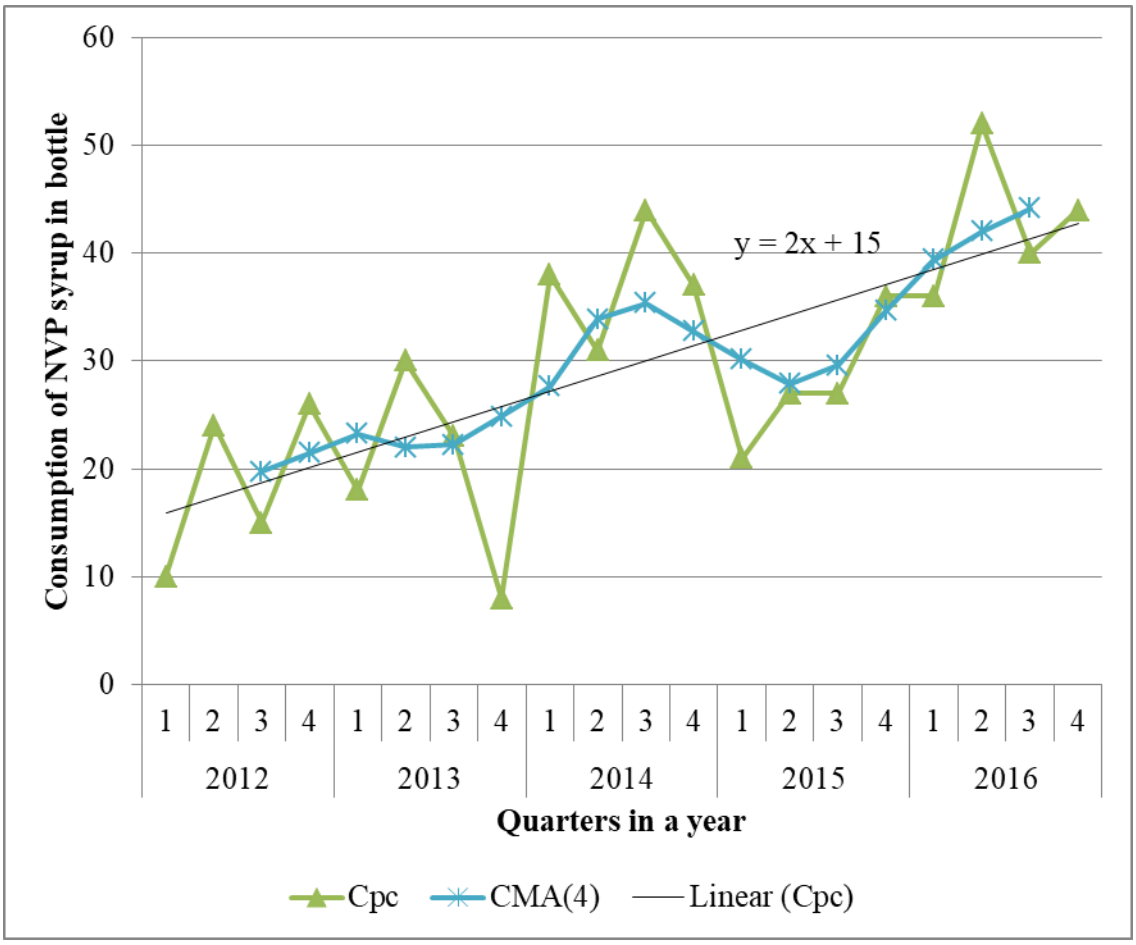


Figure 14. Times series for consumption of NVP syrup and centered moving average (CMA) at the clinic.

Consumption of NVP syrup at the clinics as in the health centres was based on the issue of NVP syrup to the patients (babies born with HIV positive mothers). Table 4.3, indicate time series analysis of NVP syrup at clinics, as in the other table above, CMA (4) was used to smooth the variation of consumption data. Classical multiplicative model ($Y_t=S_t$ x I_t x T_t) was used to get seasonal and irregular components and simple linear regression was used to calculate the forecasting and assess the fitness. The consumption data on red indicated consumption of NVP syrup forecasted for the period of 2017-2018 at the clinics.

Note: MA(4) is moving average of four periods, CMA(4) is centered moving average of four periods. S_t is seasonal trend, I_t is irregular trends, C_{pc} is consumption of Nevirapine syrup at clinics in and T_t is time trend. The table in S_t column shows that in quarter one, three and four of each year, consumption is low by 6%, 3% and 12% respectively from the baseline. Note: C_{pc} represent the consumption of nevirapine syrup at the clinics.

Table 17 Quarterly consumption of NVP syrup and forecasting at clinics

		Y_t			Y_t/CMA		Y_t/S_t		
t	Year	C_{pc}	MA(4)	CMA(4)	S_t, I_t	S_t	Deseasonalize	T_t	Forecasting
1	2012Q1	10				0.94	10	15.29	14.37
2	2012Q2	24				1.12	21	16.8	18.82
3	2012Q3	15	18.75	19.75	0.76	0.97	15	18.32	17.77
4	2012Q4	26	20.75	21.5	1.04	0.88	29	19.84	17.46
5	2013Q1	18	22.25	23.25	0.77	0.94	19	21.35	20.07
6	2013Q2	30	24.25	22	1.36	1.12	26	22.87	25.61
7	2013Q3	23	19.75	22.25	1.03	0.97	23	24.39	23.66
8	2013Q4	8	24.75	24.87	0.32	0.88	9	25.91	22.8
9	2014Q1	38	25	27.62	1.38	0.94	40	27.42	25.77
10	2014Q2	31	30.25	33.87	0.92	1.12	27	28.94	32.41
11	2014Q3	44	37.5	35.38	1.24	0.97	45	30.46	29.55
12	2014Q4	37	33.25	32.75	1.13	0.88	42	31.98	28.14
13	2015Q1	21	32.25	30.125	0.7	0.94	22	33.49	31.48
14	2015Q2	27	28	27.88	0.97	1.12	24	35.01	39.21
15	2015Q3	27	27.75	29.63	0.91	0.97	27	36.53	35.43
16	2015Q4	36	31.5	34.63	1.04	0.88	40	38.05	33.48
17	2016Q1	36	37.75	39.38	0.91	0.94	38	39.56	37.19
18	2016Q2	52	41	42	1.24	1.12	46	41.08	46.01
19	2016Q3	40	43	44.17	0.901	0.97	41	42.6	41.32
20	2016Q4	44	45.33			0.88	50	44.11	38.82
21	2017Q1					0.94		54.63	51.35
22	2017Q2					1.12		47.15	52.81
23	2017Q3					0.97		48.67	47.21
24	2017Q4					0.88		50.18	44.16

4.3b Factors associated with Stock out of NVP Syrup.

Different variables were considered to find find a correlation with stock out by using coefficient correlation of Pearson and binary logistic regression analysis was used to find out the predictive factors which predict stock out of NVP syrup

4.3.1b Factors associated with stock out of NVP syrup at OMRMD

Table 18 Factors affecting the stock out of NVP syrup at OMRMD

	Inflation rate	Delivery lead time	Closing stock	Quantity issued	Quantity received	Quantity ordered	Initial stock	Total HIV pregnant mothers	Death male babies	HIV prevalence pregnant mother	Death female babies	HIV incidence pregnant mother	Baby NVP syrup	HIV Baby prevalence	HIV Baby incidence
Pearson Correlation	.255	.136	-.323	.220	-.112	-.146	-.302	-.341	-.047	-.332	-.061	.414	-.193	-.062	-.053
P value	.079	**.003***	.052	.091	.394	.264	**.019***	**.008***	.728	**.010***	.651	**.001***	.140	.640	.690

Table above indicates that delivery lead time, initial stock and HIV prevalence and incidence or pregnant mothers are statistically significant associates with stock out of NVP syrup.

4.3.2b Factors affecting the stock out of NVP syrup at HCs

Table 19 indicated that there are no variables which is statistically significant associated with stock out of NVP syrup at health centers

Table 19. Factors affecting the stock out of NVP syrup at HCs

		HIV Baby incidence	HIV Baby prevalence	Baby NVP syrup	HIV incidence pregnant mother	HIV prevalence pregnant mother	Death female babies	Death male babies	Total HIV pregnant mothers	Initial stock	Quantity ordered HC	Quantity issued	Closing stock	Delivery lead time	Consumption	Inflation rate
Stock out	Pearson Correlation	.053	.062	.193	.414	.332	.061	.047	-.341	.302	.002	.220	.323	.063	.232	.255
	P value	.690	.640	.140	.001*	.010*	.651	.728	.008*	.012*	.987	.091	.012*	.032*	.074	0.79

Table 19 indicated that delivery time is also a factor associated with stock out of NVP syrup at HC.

4.3.3b Factors affecting the stock out of NVP syrup at the clinics.

Table 20. Factors affecting the stock out of NVP syrup at the clinics.

		HIV Baby incidence	HIV Baby prevalence	Baby NVP syrup	HIV incidence pregnant mother	HIV prevalence pregnant mother	Death female babies	Death male babies	Total HIV pregnant mothers	Initial stock	Quantity ordered	Quantity issued	Closing_stock	Delivery lead time	Consumption clinic	Inflation
Stock out	Pearson Correlation	.053	.062	.193	.414	.332	.061	.047	-.341	-.302	.002	.220	.323	.063	.146	.255
	P value	.690	.640	.140	.001*	.010*	.651	.728	.008*	.042*	.987	.091	.042*	.032*	.047*	.061

Table 20 indicated that consumption of NVP syrup and delivery time is associated with stock out NVP syrup at the clinics.

4.3.4b Integration of Quantitative and Qualitative for NVP Syrup

	Quantitative		Link	Qualitative theme	
HF	**Sources**	**Factors/variable**		**Stock out**	**Sources**
OMRMD	SYSPRO,	Delivery lead time .P value < 0.05		Delayed delivery time.	Interview informants
	DHIS,	HIV pregnant mother Prevalence rate Incidence rate		Consumption increases due to HIV new born babies.	
HC	Stock card, NVP register, EDT, Baby mother follow up reports	Delivery lead time		"Transport is a challenge, most of the time, we are receiving NVP syrup beyond the prescribed time "	
	DHIS,	HIV pregnant mothers Prevalence Incidence		Irregular orders and poor documentation	
Clinics	Stock card, reported, NVP register	Delivery lead time		"Long time deliveries is a problem"	

4.4b Development of Potential Model of Stock Level of NVP syrup

The following assumptions and notations were considered and adjusted in order to develop an optimal mathematical model of NVP syrup at OMRMD (105,106)

Assumptions

- Daily demand is stochastic, i.e daily demand is independent of each other
- Inflation rate is non-constant.
- Single supplier, manufactures and buyers are considered.
- Multiple period stochastic models.
- Health facilities use periodic review inventory policy.
- Transport cost from CMS to OMRMD and to all health facilities is constant.
- Production of pharmaceutical items is constant
- The production of items is greater than the demand.
- Storage capacity is the same to all health facilities.
- The service level is 98%
- Lead time for each level of the supply chain is constant
- CMS is only a single supplier of medicine to OMRMD
- OMRMD deliver the same lot size when the health facilities write requestion.
- Shortage of medicines is not allowed.

Notations

- AMC_T= Average monthly consumption of NVP syrup at OMRMD
- S_o=Stock on hand at order point.
- D_i= Monthly demand.
- $Lnvp_{OMRMD}$ = Lead delivery time of NVP syrup at OMRMD in days.
- $rfnvp_{OMRMD}$ = Optimal reorder frequency of NVP syrup at OMRMD in days.
- $ssnvp_{OMRMD}$ =Optimal safety stock level of NVP syrup at OMRMD

- $znvp_{OMRMD}$ = Probability of no stock out of NVP syrup at OMRMD during lead time.
- $\mu Dnvp_{OMRMD}$ =Mean demand of NVP syrup at OMRMD
- σ^2DOMRMD= Standard deviation demand of NVP syrup at OMRMD
- $\mu Lnvp_{OMRMD}$ =Mean delivery lead time of NVP syrup at OMRMD
- σ^2 LnvpOMRMD =Standard deviation delivery lead time of NVP syrup at OMRMD.
- $ROPnvp_{OMRMD}$ = Optimal maximum stock level of NVP syrup at OMRMD or reorder quantity/ point level of NVP syrup at OMRMD.

Formulation of Modeling of Stock Level of NVP syrup

The mathematical models to calculate the maximum order level (ROP) for NVP syrup involve the combination of two parts, namely cyclic inventory and safety inventory. Therefore, this is cyclic model or P model. The symbolic formula was as follows:

Cycle inventory = AMC (L_{OMRMD} + $rfnvp_{OMRMD}$) and safety inventory is Zσ (AMC ($Lnvp_{OMRMD}$ + $rfnvp_{OMRMD}$).

Mean demand of NVP syrup at OMRMD is equal to the average monthly historic consumption of NVP syrup as shown below.

$AMCnvp_{OMRMD} = \mu Dnvp_{OMRMD}$ ---------- (i).

Therefore $\mu Dnvp_{OMRMD}(Lnvp_{OMRMD}+rfnvp_{OMRMD})$ and the safety stock level of NVP syrup at OMRMD($ssnvp_{OMRMD}$) is

$ssnvp_{OMRMD} = z\sigma$ ($\mu Dnvp_{OMRMD}$ ($Lnvp_{OMRMD}+rfnvp_{OMRMD}$)----------(ii)

The demand during lead time, plus review period DL $= \sum_{i=1}^{L+r} Di$ follows a normal distribution, whose expectation and variance can be calculated similarly as before

Expected demand (E)

E[DL+rf] $= E[\sum_{i=1}^{L+r} Di] = (rfnvpOMRMD + \mu LnvpOMRMD)\mu DnvpOMRMD$…(iii)

Variance (V)

V[DL+rf] $= V[\sum_{i=1}^{L+r} Di] = (rfnvpOMRMD + \mu LnvpOMRMD)\sigma^2 DnvpOMRMD + \sigma^2 L\mu^2 DnvpOMRMD$…….(iv)

$ROPnvp_{OMRMD}$ = (iii) + (iv)

$ROPnvp_{OMRMD}$ = $\mu Dnvp_{OMRMD}(\mu Lnvp_{OMRMD} + rfnvp_{OMRMD})$ + $z\alpha \sqrt{(\mu LnvpOMRMD + rfnvpOMRMD)\sigma^2 DnvpOMRMD + \mu 2\, D\sigma^2 LnvpOMRMD}$ ---------(v)

To prevent a stock out of NVP syrup during the lead time, the service level (1- α) should be 98%. According to Namibia Essential Medicine List (NEMLIST) NVP syrup is among the vital items, in which the service level should be 95-98% (63). The higher the z score the less the item will be out of stock. Therefore, to achieve service level of 98%, z value or service factor need to be 2.05.

$ROPnvp_{OMRMD}$ = $\mu DnvpOMRMD(\mu Lnvp_{OMRMD} + rfnvp_{OMRMD})$ + $2.05\sqrt{(\mu LnvpOMRMD + rfnvpOMRMD)\sigma 2\, DnvpOMRMD + \mu 2\, D\sigma 2\, LnvpOMRMD}$ .....(vi)

The quantity to order ($ROPnvp_{OMRMD}$) is replenishment level minus quantity on hand.

$ROPnvp_{OMRMD} = Qmax - S_o$----------(vi)

4.4.1b Delivery Time of NVP Syrup at OMRMD

The expected time is the expected replenishment time of NVP syrup and actual replenishment time is the real time it took to replenish each order in the data provided (2012-2016). Positive numbers are the number of days over the expected time and negative numbers mean that the delivery arrived earlier than the expected time. With this information, the researcher was able to find the standard deviation in lead time, hence safety stock as indicated in table 21.

Note. C_p represents the consumption of NVP syrup at OMRMD

Table 21 Replenishment time for NVP syrup at OMRMD.

Years in quarter	Actual replenishment time (days)	Expected replenishment time (days)	Variance	C_p
2012Q1	0	0	0	251
2012Q2	56	30	26	275
2012Q3	49	30	19	271
2012Q4	141	30	111	567
2013Q1	53	30	23	374
2013Q2	37	30	7	396
2013Q3	17	30	-13	379
2013Q4	71	30	41	771
2014Q1	21	30	-9	499
2014Q2	16	30	-14	516
2014Q3	33	30	3	487
2014Q4	33	30	3	977
2015Q1	20	30	-10	622
2015Q2	27	30	-3	638
2015Q3	32	30	2	594
2015Q4	9	30	-21	1182
2016Q1	37	30	7	747
2016Q2	42	30	12	759
2016Q3	38	30	8	702
2016Q4	0	0	0	1386
			192	12393

Therefore, the total variance in a quarter / number of observations =192/20 = 9.6 days in a quarter which is equivalent to 3 months. For a month =9.6/3= 3 days, therefore replenishment time is 10+3 = 13. According to PSOP(65) the replenishment time is 2 weeks, which is equivalent to 10 working days. 10+3=13 days. Hence the standard deviation of lead time at OMRMD ($\sigma LTnvp_{OMRMD}$) = 13 days. Thirteen (13) days signifies the average amount of time it takes to restock, after taking into account the variability in the actual time that orders have been received in the past. This is also the amount of time that safety stock will have to hold at OMRMD over until new NVP syrup arrives.

4.4.2b Optimal Reorder point of NVP syrup at OMRMD (ROPnvpOMRMD)

For the demand average at OMRMD ($\mu Dnvp_{OMRMD}$) = $AMCnvp_{OMRMD}$ Therefore $AMCnvp_{OMRMD}$ = Total consumption of NVP syrup at OMRMD/total months=12393/60= 196 B/240ml of NVP syrup = µD. For the daily demand of NVP syrup at OMRMD =12393/1200 =10. Therefore 10 B/240ml of NVP syrup. The safety stock($ssnvp_{OMRMD}$) is 13 x 10= 130 B/240ml of NVP syrup (Daily consumption/demand). But for the safety stock level, we need to consider the service level ($znvp_{OMRMD}$). The service level = 98%. From the normal distribution chart, the service factor for the service level of 98% =2.05. The $ssnvp_{OMRMD} = Z \times \Sigma LTnvp_{OMRMD} \times \mu Dnvp_{OMRMD}$ =2.05 x 13 x 10 =266 B/240ml of NVP syrup. Safety stock for NVP syrup at OMRMD =266 B/240ml.

$ROPnvp_{OMRMD}$ = 10 x 13 +266 = 396 B/240ml of NVP syrup.

= 396 B/240ml is the optimal reorder level or quantity.

4.4.3b Optimal Reorder Frequency of NVP syrup at OMRMD

Total number of orders required for 2012-2016/ number of orders made by OMRMD from 2012-2016.

$rfnvp_{OMRMD}$ = 60 orders needed /32 orders requested by OMRMD = 1.8 months, which is equivalent to 1.8 x 4 weeks = 7 weeks.

The Optimal reorder frequency of NVP syrup at OMRMD is 7 weeks.

4.4.4b Optimal Model of NVP syrup at Health centres.

The following assumptions and notations were considered and adjusted in order to develop an optimal model of NVP syrup at Health centers (HCs) (122,127)

Assumptions

- Daily demand is stochastic, i.e daily demand is independent of each other
- Inflation rate is non-constant.
- Single supplier, manufactures and buyers are considered.
- Multiple period stochastic models.
- Health facilities use periodic review inventory policy.
- Transport cost from OMRMD to all HCs is constant.
- Production of pharmaceutical items is constant
- The production of items is greater than the demand.
- Storage capacity is the same to all health centres.
- The service level is 96%
- Lead time for each level of the supply chain is different

- OMRMD is only a single supplier of medicine to health centers
- OMRMD deliver the same lot size when the health facilities write requestion.
- Shortage of medicines is not allowed.

Notations

- $AMCnvp_{HC}$ = Average monthly consumption of NVP syrup at HC
- S_o=Stock on hand at order point.
- D_i= Monthly demand of NVP syrup at HC.
- $Lnvp_{HC}$ = Lead delivery time of NVP syrup at HC in days.
- $Rfnvp_{HC}$ = Optimal reorder frequency of NVP syrup at HC in days.
- $Ssnvp_{HC}$ =Optimal safety stock level of NVP syrup at HC
- $Znvp_{HC}$ = Probability of no stock out of NVP syrup at HC during lead time.
- μDnvpHC =Mean demand of NVP syrup at HC
- σ^2DnvpHC= Standard deviation demand of NVP syrup at HC
- $\mu Lnvp_{HC}$ =Mean delivery lead time of NVP syrup at HC
- σ^2 LnvpHC =Standard deviation delivery lead time of NVP syrup at HC.
- $ROPnvp_{HC}$ = Optimal maximum stock level of NVP syrup at HC or reorder quantity/ point level of NVP syrup at HC.

Formulation of Modeling of Stock Level

The mathematical models to calculate the maximum order level (ROP) for NVP syrup involve the combination of two parts, namely cyclic inventory and safety inventory. Therefore, this is cyclic model or P model. The symbolic formula was as follows:

Cycle inventory = AMC ($Lnvp_{HC}$ + $rfnvp_{HC}$) and safety inventory is Zσ (AMC ($Lnvp_{HC}$ + $rfnvp_{HC}$).

Mean demand of NVP syrup at HC is equal to the average monthly historic consumption of Mrdt as shown below.

$AMCnvp_{HC} = \mu Dnvp_{HC}$ ---------- (i).

Therefore $\mu Dnvp_{HC}(Lnvp_{HC}+rfnvp_{HC})$ and the safety stock level of NVP syrup at HC($ssnvp_{HC}$) is

$Ssnvp_{HC} = z\sigma (\mu Dnvp_{HC} (Lnvp_{HC}+rfnvp_{HC})$----------(ii)

The demand during lead time, plus review period DL $= \sum_{i=1}^{L+r} Di$ follows a normal distribution, whose expectation and variance can be calculated similarly as before

Expected demand (E)

$E[DL+rf] = E[\sum_{i=1}^{L+r} Di] = (rfnvpHC + \mu LnvpHC)\mu DnvpHC$…(iii)

Variance (V)

$V[DL+rf] = V[\sum_{i=1}^{L+r} Di] = (rfnvpHC + \mu LnvpHC)\sigma^2 DnvpHC + \sigma^2 L\mu^2 DnvpHC$…….(iv)

$ROPnvp_{HC}$ = (iii) + (iv)

$ROPnvp_{HC} = \mu Dnvp_{HC}(\mu Lnvp_{HC} + rfnvp_{HC}) + z\alpha\sqrt{(\mu LnvpHC + rfnvpHC)\sigma^2 DnvpHC + \mu 2 D\sigma^2 LnvpHC}$ ---------(v)

To prevent a stock out of NVP syrup at HC during the lead time, the service level (1- α) should be 96%. According to Namibia Essential Medicine List (NEMLIST) NVP syrup is among the vital items, in which the service level should be 95-98% (63). The higher the z score the less the item will be out of stock. Therefore, to achieve service level of 98%, z value or service factor need to be 1.96

Therefore, $ROPnvp_{HC}$ = $\mu Dnvp_{HC}$ ($\mu Lnvp_{HC}$ + $rfnvp_{HC}$) + $2.05\sqrt{(\mu LnvpHC + rfnvpHC)\sigma 2\, DnvpHC + \mu 2\, D\sigma 2\, LnvpHC}$ …….(vi)

The quantity to order ($ROPnvp_{HC}$) is replenishment level minus quantity on hand.

$ROPnvp_{HC} = ROPnvp_{HC} - S_o$----------(vi)

4.4.5b Delivery Lead Time of NVP syrup at HCs

Figure 22, indicates that, the expected time is the expected replenishment time of NVP syrup and actual replenishment time is the real time it took to replenish each order in the data provided (2012-2016). Positive numbers are the number of days over the expected time and negative numbers mean that the delivery arrived earlier than the expected time. With this information, the researcher was able to find the standard deviation in lead time hence safety stock.

Note: C_{ph} represents the consumption of nevirapine syrup at health centres.

Table 22 Delivery Lead Time at HCs in Oshana region

Year	Quarter	Actual replenishment time (days)	Expected replenishment time (days)	Variance	C_{ph}
2012	1	44	15	29	24
	2	30	15	15	87
	3	48	15	33	145
	4	17	15	2	91
2013	1	33	15	18	142
	2	61	15	46	140
	3	30	15	15	127
	4	28	15	13	189
2014	1	22	15	7	69
	2	28	15	13	158
	3	47	15	32	134
	4	54	15	39	171
2015	1	43	15	28	88
	2	49	15	34	152
	3	41	15	26	125
	4	22	15	7	142
2016	1	26	15	11	118
	2	23	15	8	184
	3	25	15	10	133
	4	31	15	16	149
		Total		402	2550

Total variance in a quarter / number of observations=402/20 =20 days in a quarter which is equivalent to 3 months. For a month =20/3=6 approximately is 6 days in a month, therefore there is an extra of 7 days. The replenishment time is 1 week, which is equivalent to 5 working days. 5+6=11 days. Therefore, there is an extra of 6 days.

4.4.6b Optimal Reorder Point of NVP Syrup at HCs.(ROPnvpHC)

Hence the standard deviation of lead time of NVP syrup at HC (σLTnvpHC) =11 days. Twelve(12) days signify the average amount of time it takes to restock, after taking into account the variability in the actual time that orders have been received in the past. This is also the amount of time that safety stock will have to hold at health centers over until new NVP syrup arrives.

For the demand average (μDnvpHC) = AMCph therefore, AMCph=Total consumption/total months=2568/60= 43 B/240ml of NVP syrup= μDnvpHC. For the daily demand of NVP syrup at HCs =2568/1200=. Therefore 2B/240ml of NVP syrup. The safety stock of NVP syrup at HCs (SSnvpHC) is 11 x 2= 22 B/240ml of NVP syrup(Daily consumption/demand).

But for the safety stock level needed to consider the service level (z). The service level =96%. From the normal distribution chart, the service factor for the service level of 96% =1.75. The $ssnvp_{HC} = Z \times \sigma LTnvp_{HC} \times \mu Dnvp_{HC}$ =1.75 x2 x 11 = 38 B/240ml of NVP syrup. Safety stock for NVP syrup at HCs =92 B/240ml

Optimal reorder point = daily demand x lead time + safety stock

$$= \mu Dnvp_{HC} \text{ x } \sigma LTnvp_{HC} + ssnvp_{HC}$$

$$= 2 \text{ x } 11 + 38 = 60 \text{ B/240ml}$$

4.4.7b Optimal Reorder Frequency of NVP syrup at HC

The total number of orders needed from 2012-2016/ number of orders requested by the HCs

= 60/57=1.05 x 4weeks = approximately four weeks.

= Optimal reorder frequency of NVP syrup at HCs is 4 weeks.

4.4.8b Optimal Model of NVP syrup at the Clinic.

The following assumptions and notations were considered and adjusted in order to develop an optimal mathematical model of NVP syrup at the clinics (105,106)

Assumptions

- Daily demand is stochastic, i.e daily demand is independent of each other
- Inflation rate is non-constant.
- Single supplier, manufactures and buyers are considered.
- Multiple period stochastic models.
- Health facilities use periodic review inventory policy.
- Transport cost from OMRMD to clinics is constant.
- Production of pharmaceutical items is constant
- The production of items is greater than the demand.
- Storage capacity is the same to all clinics.
- The service level is 96%
- Lead time for each level of the supply chain is different
- OMRMD is only a single supplier of medicine to clinics

- OMRMD deliver the same lot size when the health facilities write requisition.
- Shortage of medicines is not allowed.

Notations

- $AMCnvp_C$ = Average monthly consumption of NVP syrup at clinics
- S_o=Stock on hand at order point.
- D_i= Monthly demand of NVP syrup at clinics.
- $Lnvp_C$ = Lead delivery time of NVP syrup at clinics in days.
- $Rfnvp_C$ = Optimal reorder frequency of NVP syrup at clinics in days.
- $ssnvp_C$ =Optimal safety stock level of NVP syrup at clinics
- $Znvp_C$ = Probability of no stock out of NVP syrup at clinics during lead time.
- μDnvpC =Mean demand of NVP syrup at clinics
- σ^2DnvpC= Standard deviation demand of NVP syrup at clinics
- $\mu Lnvp_C$ =Mean delivery lead time of NVP syrup at clinics
- σ^2 LnvpC =Standard deviation delivery lead time of NVP syrup at clinics.
- $ROPnvp_C$ = Optimal maximum stock level of NVP syrup at clinics or reorder quantity/ point level of NVP syrup at clinics.

Formulation of Modeling of Stock Level

The mathematical models to calculate the maximum order level (ROP) for NVP syrup involve the combination of two parts, namely cyclic inventory and safety inventory. Therefore, this is cyclic model or P model. The symbolic formula was as follows:

Cycle inventory = AMC ($Lnvp_C$ + $rfnvp_C$) and safety inventory is Zσ (AMC ($Lnvp_C$ + $rfnvp_C$).

Mean demand of NVP syrup at the clinics is equal to the average monthly historic consumption of NVP syrup as shown below.

$AMCnvp_C = \mu Dnvp_C$ ---------- (i).

Therefore $\mu Dnvp_C(Lnvp_C+rfnvp_C)$ and the safety stock level of NVP syrup at HC($ssnvp_C$) is

$Ssnvp_{HC} = z\sigma\ (\mu Dnvp_C\ (Lnvp_{HC}+rfnvp_C)$----------(ii)

The demand during lead time, plus review period DL $= \sum_{i=1}^{L+r} Di$ follows a normal distribution, whose expectation and variance can be calculated similarly as before

Expected demand (E)

$E[DL+rf] = E[\sum_{i=1}^{L+r} Di] = (rfnvpC + \mu LnvpC)\mu DnvpC$…(iii)

Variance (V)

$V[DL+rf] = V[\sum_{i=1}^{L+r} Di] = (rfnvpC + \mu LnvpC)\sigma^2 DnvpC + \sigma^2 L\mu^2 DnvpC$…….(iv)

$ROPnvp_C$ = (iii) + (iv)

$ROPnvp_C = \mu Dnvp_C(\mu Lnvp_C + rfnvp_C) + z\alpha\sqrt{(\mu LnvpC + rfnvpC)\sigma^2 DnvpC + \mu 2\, D\sigma^2 LnvpC}$ ---------(v)

To prevent a stock out of NVP syrup at the clinics during the lead time, the service level (1- α) should be 98%. According to Namibia Essential Medicine List (NEMLIST) NVP syrup is among the vital items, in which the service level should be 95-98% (63). The higher the z score the less the item will be out of stock. Therefore, to achieve service level of 96%, z value or service factor need to be 1.96.

Therefore, $ROPnvp_C = \mu Dnvp_C (\mu Lnvp_C + rfnvp_C) + 2.05\sqrt{(\mu LnvpC + rfnvpC)\sigma 2\, DnvpC + \mu 2\, D\sigma 2\, LnvpC}$ …….(vi)

The quantity to order ($ROPnvp_C$) is replenishment level minus quantity on hand.

$ROPnvp_C = ROPnvp_C - S_o$----------(vi)

4.4.9b Delivery Time of NVP syrup at Clinics

In the following tables for safety stock, the monthly actual replenishment time, expected replenishment time, variances and consumption were broken down quarterly in a year. The expected time is the expected replenishment time of NVP syrup and actual replenishment time is the real time it took to replenish each order in the data provided (2012-2016). Positive numbers are the number of days over the expected time and negative numbers mean that the delivery arrived earlier than the expected time. With this information, the researcher was able to find the standard deviation in lead time hence safety stock. Note: C_{pc} represent consumption of nevirapine at the clinics

Table 23 Delivery Lead Time of NVP syrup at Clinics in Oshana region

Year	Quarter	Actual replenishment time (days)	Expected replenishment time(days)	Variance	C_{pc}
2012	1	43	15	28	14
	2	41	15	26	19
	3	66	15	51	18
	4	35	15	20	17
2013	1	62	15	47	20
	2	61	15	46	26
	3	38	15	23	24
	4	33	15	18	23
2014	1	50	15	35	26
	2	66	15	51	32
	3	50	15	35	30
	4	21	15	6	28
2015	1	71	15	56	32
	2	30	15	15	39
	3	35	15	20	35
	4	32	15	17	33
2016	1	20	15	5	37
	2	7	15	-8	46
	3	28	15	13	41
	4	13	15	-2	39
	Total			502	679

Total variance in a quarter / number of observations = 502/20=25 days in a quarter which is equivalent to 3 months. For a month =25/3 = 8 approximately is 8 days in a month, therefore there is an extra of 8 days. The replenishment time is 1 week, which is equivalent to 10 working days. 5+8 = 13 days. Therefore, there is an extra of 8 days.

Hence the standard deviation of lead time of NVP syrup at clinics ($\sigma LTnvp_C$) = 13 days. 13 days signifies the average amount of time it takes to restock, after taking into account the variability in the actual time that orders have been received in the past. This is also the amount of time that safety stock will have to hold at clinics over until new NVP syrup arrives.

4.4.10b Optimal Reorder Point Level of NVP syrup at Clinics (ROPnvpC)

For the demand average **(**$\mu Dnvp_C$)=$AMCnvp_C$, therefore $AMCnvp_C$ =Total consumption/total months=679/60= 10 B/240ml of NVP syrup= $\mu Dnvp_C$. For the daily demand of NVP syrup at clinics =679/1200= 0.5 = 1. Therefore 1 B/240ml of NVP syrup. The safety stock of NVP syrup at clinics ($SSnvp_C$) is 13 x 1= 13 B/240ml of NVP syrup (Daily consumption/demand).

But for the safety stock level needed to consider the service level (z). The service level = 96%. From the normal distribution chart, the service factor for the service level of 96% =1.75. The $ssnvp_C$= $Z \times \sigma LTnvp_C \times \mu Dnvp_C$ =1.75 x13 x 1 = 22 B/240ml of NVP syrup. Safety stock for NVP syrup at clinics = 22 B/240ml.

= Daily demand x delivery lead time + safety stock.

$\mu D\ nvp_C \times \sigma LT\ nvp_C + ssnvp_C = 1 \times 13 + 22 = 35$

Reorder point level of NVP syrup at clinics is 35 B/240ml.

4.4.11b Reorder Frequency of NVP syrup at the clinics

= 60(required orders) /56(Order made) = approximately 4 weeks.

4.5b Simulation of Potential Models of Stock Level.

The optimal models were simulated in order to evaluate and validate the model based on two variables, which are average demand and lead time.

Table 24 Simulated demands of NVP syrup

Category	Quarter	Monthly demand	Probability	Cumulative probability	Random number interval	Random number	Demand
OMRMD	1	871	0.209	0.209	0 - 208	506	809
	2	880	0.212	0.421	209 - 420	622	1591
	3	809	0.195	0.616	421 - 615	497	809
	4	1591	0.383	1.000	616 - 999	740	1591
						Total	**4800**
						Avg daily demand	**13**
HCs	1	117	0.184	0.184	0 - 183	866	176
	2	177	0.278	0.462	184 - 461	462	167
	3	167	0.262	0.724	462- 723	720	167
	4	176	0.276	1.000	724 - 999	73	117
						Total	**627**
						Avg daily demand	**2**
Clinics	1	51	0.262	0.262	0 - 262	464	52
	2	52	0.268	0.530	262 - 529	161	51
	3	47	0.242	0.772	530 - 771	618	47
	4	44	0.227	1.00	772- 999	924	44
						Total	**194**
						Avg daily demand	**1**

Table 24 showed the simulated average demand in different facilities for the next four months

Table 25 Simulated lead time (days) of NVP syrup

Category	Quarter	Lead time (days)	Probability	Cumulative probability	Random number interval	Random number	Lead time
OMRMD	1	7	0.11	0.11	0 - 10	38	18
	2	18	0.29	0.40	11 - 39	1	7
	3	9	0.14	0.54	40 - 53	44	9
	4	29	0.46	1.00	54 - 99	71	29
						Total	**63**
						Avg lead time	**4**
HCs	1	3	0.12	0.12	0 - 11	57	12
	2	8	0.31	0.43	12 - 42	62	12
	3	3	0.12	0.55	43 - 54	67	12
	4	12	0.46	1.00	55 - 99	26	8
						Total	**44**
						Avg lead time	**4**
Clinics	1	6	0.31	0.31	0 - 30	19	6
	2	8	0.42	0.73	31 - 72	68	8
	3	4	0.21	0.94	73 - 93	35	8
	4	1	0.05	0.99	94 - 98	57	8
				1.00	99	**Total**	**30**
						Avg lead time	**3**

Table 25 shows the simulated average lead time of different facilities for the next four months.

4.5.1b Validation of the Potential Model of NVP syrup

The models were validated by comparing predicted models results and the simulated results

$ROPnvp_{OMRMD}$ = Daily demand x average lead time + safety stock =

= 9 x 16 + 266 = 410 B/240ml of NVP syrup (simulated from the model)

$ROPnvp_{OMRMD}$ = 435 B/240ml of NVP syrup (predicted from the model)

Validation accuracy = 410/435 = 94% accuracy

$ROPnvp_{HC}$ = 2 x 11 + 92 = 114B/240ml

Validation accuracy = 114/164 = 71%

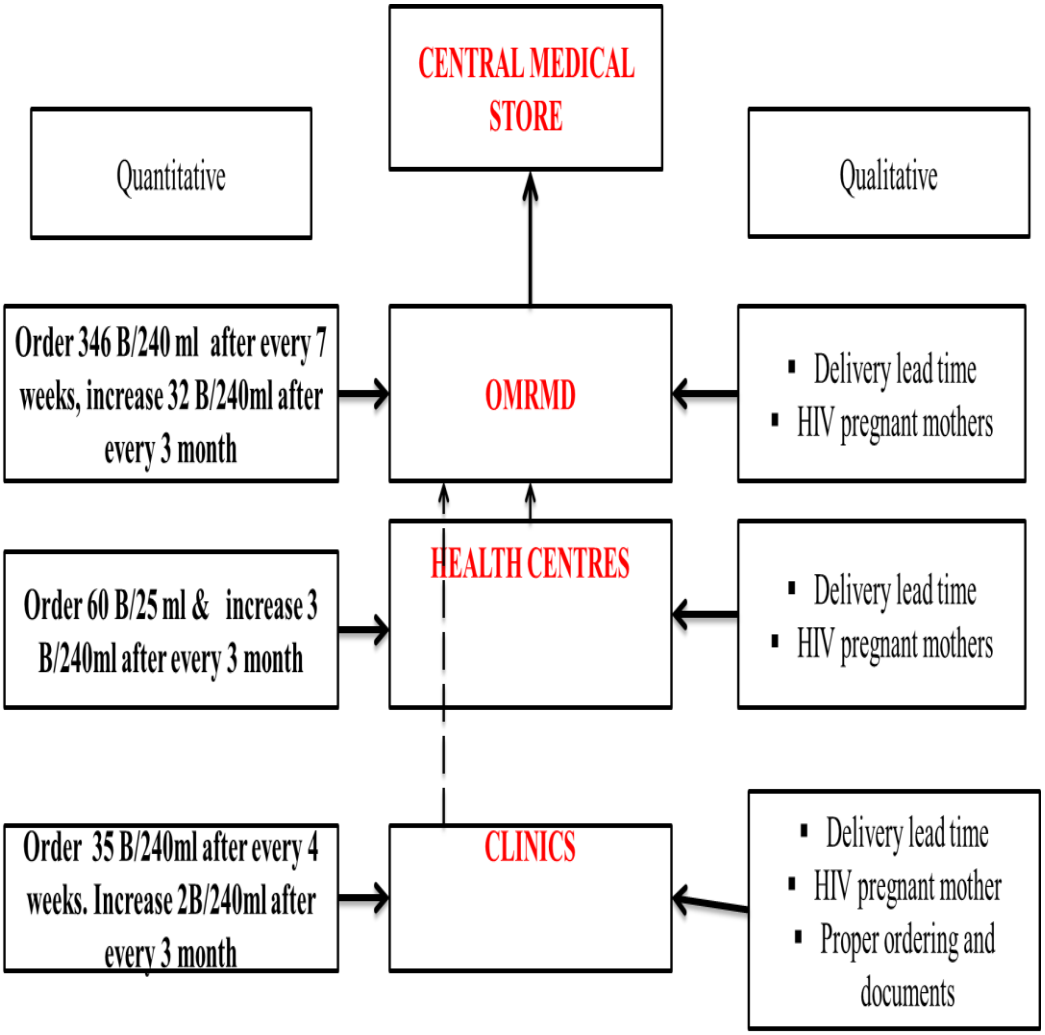
ROPnvpc = 1 x 7 +78 = 85B/240ml

Validation accuracy = 85/116 = 73%

The optimal supply chain models of NVP syrup are accurate by more than 70%

4.5.2b Nevirapine Model Presentation

Figure 12. Nevirapine test kit model presentation.



CHAPTER 5: DISCUSSION, CONCLUSION AND RECOMMENDATION

5.1 Introduction

This chapter explains in detail, the findings of quantitative data which triangulated with qualitative findings with reference to the objectives defined in chapter 1, section 1.4. The ultimate goal of the study was to generate optimal, mathematical supply-chain models for NVP syrup and mRDT in Oshana region, Namibia. The models produced were compared with the results of similar studies conducted in other countries. The supply chain optimal models were evaluated by Monte Carlo simulation, which takes random samples from the distribution of consumption and delivery times in order to produce a series of values for use in the model. Modeling mimics real-life situations in the supply chain of NVP syrup and mRDT. Modeling was complemented by detailed information gathered in interviews with key informants, professionals employed in various capacities in the supply chain of essential medicines in Oshana region. The implications, impacts and limitations of the study were also discussed and recommendations were made at national, regional and facility levels in the context of objectives, the literature review, the quantitative and qualitative findings of the study, and its recorded discussions. The findings from the study confirmed the value of public health facilities by using an optimal or potential, mathematical model of stock levels. It is a valuable tool for depicting a number of variables: reorder level, maximum-stock level, average monthly consumption, safety-stock, lead time and prediction of stock-out and prevention. Models presentation to prevent stock-outs were discussed. Conclusions relevant to the findings and objectives outlined in Chapter 1, paragraph 1.4, were also discussed in this chapter. Findings are presented under the respective headlines of the four objectives of the study.

5.2 Discussion

5.2.1 Examine the consumption rates of mRDT and NVP syrup

In the first instance, this objective was achieved by means of a quantitative approach which was intergreted by qualitative method and interpreted in order to produce new insight regarding the supply chain system of mRDT and NVP syrup in Oshana region. The Intermediate Oshakati Hospital (IHO) was excluded from the survey because it receives pharmaceutical supplies directly from the Central Medical Store (CMS). This objective is foremost in importance of compiling a set of guidelines (or variables) to make possible the execution of a potential mathematical model of stock levels of mRDT and NVP syrup. This study is the first of its kind to be conducted in Oshana region, in fact, in the entire country, which involves the Oshakati Multi-regional Medical store (OMRMD), all health centers and all clinics in the region. Most studies of modeling of stock level of medicines conducted in other countries were based on an industrial level (108).

Descriptive statistics of trend of consumption of mRDT at Oshakati Multi Region Medical Depot (OMRMD) for five years (2012 – 2016), as indicated in figure 8, shows that the consumption trend of mRDT is fluctuating up and down with cyclic and seasonal characteristics. Figure 8 indicates also the irregular trends, in which there is no any clear explanation regarding the irregular trends (10).Despite the fact that trends varies, there is a positive, secular trend in consumption of mRDT at OMRMD, which is depicted in figure 8. This means, the consumption of mRDT at Oshakati MultiRegional Medical Depot (OMRMD) is increasing in every quarter by almost 12 P/25. This increase can be due to Malaria policy which require every patient who is presenting with fever at public

health facilities to be screened for malaria, temperature, population growth and an increase in HIV prevalence in Oshana region. The prevalence is now at 17%. Different studies have shown that increase of HIV also increases malaria, especially in unstable malaria transmission areas (9,23,25). Oshana is one of the unstable malaria transmission region in Namibia. In order to address the issue of future consumption of mRDT, all irregularities, seaasonalities and other unknown confounding variables should be put into consideration as illustrated in table 1. Because the consumption is keeping increases, then the multiplicative classical model is the best way to use so that, future consumption of mRDT can be known (37) as illustrated in table 1. The same features are illustrated in figure 9, which is consumption rates of mRDT at Health Centres and figure 10 which is consumption of mRDT at the clinics. Increase of mRDT consumption rates was also explained by informants from different level of supply chain in the region. They pointed out the issue of rainfall, stagnant waters, especially in the informal settlement and the policy which require every patient with fevr to be tested for malaria.

In figure 8, despite trend variations of mRDT consumption at OMRMD, there is an upward secular trend and cyclic feature in consumption of mRDT at OMRMD. There is an increase consumption in first and third quarters. The first quarter is January, February and March. These are the months where in Namibia is expecting to receive rain, it is obvious that there will be an increase of mosquito during the first quarter, hence increase in consumption of mRDT, due to the number of people who tested for malaria (8). Figure 8,9 and 10, show that even during the winter season there are increases in consumption of mRDT. This may be explained, that limited number of mosquitoes are available and active as far as the temperature is not below 10 °C. (8). In addition the

increase of mRDT, could be due to increasing movement across the northern border, bringing in Angolans that seek treatment in Namibia (29). The growth in the Namibian population, rising at a rate of 1.8% a year, can also be a contributing factor (14). In addition, a substantial upturn in consumption trends of mRDT (quantity issued to health facilities) between 2015 and 2016, became evident after implementation of new malaria guidelines in 2015, requiring that all patients with fever be tested for malaria. Consequently, health facilities have increased their orders of mRDT, producing higher quantities drawn from OMRMD. The predicted mRDT consumption at OMRMD was shown in table 1.

This variation in time-series trends were smoothed in order to establish a baseline,(see figure 8,9 and 10) known as a centered moving average (CMA), which is presented in table 1.2 and 3. Findings indicated that consumption during the second and third quarters is below baseline by 9% and 22%, respectively, while consumption in the fourth quarter is 44% above baseline. Higher consumption of mRDT can be explained by the influx of people to Oshana region towards the end of the fourth quarter, when large numbers arrive for the holidays and to prepare Pearl millet (Mahangu) fields (109). This influx requires health centres and clinics to increase orders of mRDT to OMRMD, producing a corresponding higher consumption at OMRMD. Also the onset of the rainy season is a determining factor as explained above (110). Below baseline consumption is associated with the winter season, during which the consumption always drops.

First-quarter consumption sits on the baseline. Here a reverse migration takes place, in which many people return to places of employment around the country. On the other hand, it’s still the rainy season, during which more cases of malaria are expected. This

finding was confirmed by a study conducted in Namibia whose aim was to reveal ways of improving malaria diagnosis and treatment in the country. Another study, conducted in Kenya, of perceptions regarding malaria and acceptance of treatment was conducted in greater Garissa, Northeastern province, (111, 112) also confirmed these findings. The seasonal fluctuations in consumption of mRDT were likewise confirmed by key informants, who indicated that consumption tends to increase during the rainy and festival seasons which begin early in November and end early in January.

The consumption rates and trends for NVP syrup for all health facilities studied in Oshana is almost with similar features as the one in figure 12,13 and 14. Meaning it has also the seasonalities, irregularities and positive secular trend as indicated in figure 12, 13 and 14 with seasonalities, irregularities and positive secular trends. The increase of consumption rates might be due to increase of HIV pregnant mothers, which is at 16.1 % in Oshana region (11), mothers missed their ANC visit and some of HIV pregnant mothers attend ANC at the late stage when they left with a few months to deliver (11).Other explanation can be the increase was predictable in the context of implementation of new ART guidelines published in 2015, especially in the PMTCT programme in which all babies born to HIV-positive mothers are required to receive NVP syrup for a period of at least six months until the Deoxyribonucleic acid-polymerase chain reaction-HIV (DNA-PCR-HIV) test or rapid test confirms the status of the baby (86), increase of HIV/AIDS test awareness campaign. The increase of consumption due to awareness campaign was also supported by the study conducted in Rundu, Namibia, on factors influencing PMTCT outcomes. The study findings showed that the routine-awareness campaign, which is conducted by health workers at various health facilities,

contributed to an increased consumption of Antiretroviral (ARV) medication including NVP syrup (113, 114), population growth (86). An increase of fluctuation in consumption was also discovered in a similar study conducted on time-series modeling and forecasting, where factors causing fluctuation were identified, such as patient behaviour, poor recording systems and policy changes (110). This increase in consumption was also confirmed by supply-chain informants who noted the impact of one policy change in the ART guideline, in which the health facilities were required to order more NVP syrup from OMRMD so that to meet the demand per ART guideline. Also informants noted that "It is a custom for most of Ovambo people, from different part of the country to visit their homeland during the festival season and preparation of the pearl millet field before the rainy season" (115). Pearl millet is known as Mahangu in Oshivambo language, this is a staple food for Ovambo people. Festival season is falling under the fourth quarter of the year, November and December in particular. Ovambo people are the largest tribe in Namibia, which comprising half of Namibian's population. It originates from northern part of Namibia, this tribe occupies four regions in the north, namely Oshana, Omusati, Ohangwena and Kunene. Oshana region being the centre of economic activities and second largest after Windhoek, which is a Namibia capital city (75). "This caused many people visit health facilities in the Oshana region during this period, these facilities need to order more NVP syrup from OMRMD to meet the demand". As shown by Central moving Average (CMA), which is presented as a baseline after smoothing out the fluctuation of the consumption indicated that the consumption of NVP syrup at OMRMD was relatively constant from 2012 until the fourth quarter of 2015 (figure 12). This was due to the fact that NVP syrup was not frequently used in

PMTCT. Before implementation of ART guideline NVP syrup documentation in PMTCT was very poor.

Table 15, shows the forecasting of NVP syrup at OMRMD based on the historical data for 2012 – 2016. The drastic increase in consumption of NVP syrup was caused by factors explained above. After seasonal adjustment with the application of a multiplicative model, assume that factors causing variations in NVP syrup consumption are not necessarily independent, but may also affect one another (115). The forecasting column, based on simple linear regression, indicates that in every fourth quarter there is an increase of NVP syrup consumption by almost 37%, while the first three quarters are 17%, 19% and 28% below baseline consumption respectively. The reason of this increase of 37% consumption of NVP syrup in the fourth quarter is explained above. Based on these findings, health professionals who are responsible for ordering can put it in his mind that during the fourth quarter based on the reason given by informants and the trend of consumption, OMRMD can order more of NVP syrup from the Central Medical Store (CMS) in order to meet increased demand during the fourth quarter. Though there are some dissimilarities from each other, in terms of consumption, these figures, as other figures of mRDT, shows almost the same feature in the trend of NVP syrup consumption, with the positive secular trend and cyclic characteristics, mainly the consumption is high at the fourth quarter of each year and the other quarter the consumption is decreased especially in the third quarter. The reasons or the factors are the same as explained above at OMRMD. Additional factors causing fluctuations were identified, such as behaviour of patients in this case mothers with HIV babies, regarding ARV medication.; some share decide to share her baby medicines with other babies, frequently come to the health

centres or clinics with the complaints of medicines lost e.g. theft, stop giving a baby, NVP syrup for religious or traditional reasons. Poor recording systems (e.g. Ones that duplicate patients identified by EDT), and policy changes, such as explained by the new ART guidelines (115) are among these factors. These imply that supply chain at different levels is linked to another level. For example unavailability or availability of one factor or factors at the higher level of the supply chain can have an effect at the low level of supply chain and vice versa (10,19).

The prediction of future consumption of NVP syrup at health centers and clinics was represented by the table 16 and 17 respectively, based on the historical data for 2012 – 2016. In order to attempt prediction of stochastic variables in the consumption of NVP syrup at HCs, variations in NVP syrup consumption were smoothed using centered-moving-average (CMA) techniques as indicated in table 16. Table 16,shows that consumption of NVP syrup at HCs in the first quarter is 33% below baseline consumption. Again, this fluctuation can be explained by the large number of people who return to work places in different parts of the country after the festival season and preparation of pearl millet ends. Consumption in the second, third and fourth quarters is above the baseline at 16%, 7% and 11% respectively. There is no immediate explanation for this increase. Perhaps it is due to growing awareness among HIV-positive mothers regarding the importance of the PMTCT programme (119). In table 17, the time series trend shows that in quarter one, three and four of each year, consumption of NVP syrup at the clinics is low by 6%, 3% and 12% respectively from the baseline. There is no clear explanation on how the consumption is lower in the one, three and fourth quarters, and the second quarter is 12% above the baseline. Perhaps is due to poor documentation as

stated by many informants “at the health facilities, clinics in particular the documentation is very poor simply because of the shortage of trained staff and workload”. Poor documentation at the clinics has been reported in different studies (69).

This figure accounts for 35% of the total consumption of NVP syrup, where the lowest consumption was 2%. This indicates that when health centres (HCs) and clinics ordered NVP syrup from OMRMD, they usually received the product in a quantity between one and 70 bottles. Despite the fact that the mean monthly consumption of NVP syrup at OMRMD is 196 bottles. Graph 15 also shows that the frequency decreases as consumption of NVP syrup issued to health facilities increases. This finding is significant as it indicates the behaviour of the consumption-distribution curve for NVP syrup at OMRMD. Namely, the more NVP syrup consumption at OMRMD deviates from the average monthly consumption, the more the distribution is skewed to the right. Due to the distribution pattern, the hypothesis were formulated that the distribution of consumption of NVP syrup at OMRMD conforms to a gamma-probability distribution model. The finding was confirmed by using a chi-square goodness-of-fit test, which depicted that distribution follows a curve whose shape is similar to a gamma-probability distribution presented in the literature (116). The aim to identify probability distribution which fits the consumption of NVP syrup at OMRMD is important because an optimal mathematical model can be developed based on the kind of probability distribution identified. Employing the model, OMRMD will be able to issue stock of NVP syrup efficiently, and also predict when stock-outs are more likely to occur, and consequently adjust the quantities of NVP syrup issued as recommended in several studies described in the literature review (117). An optimal mathematical model, based on the distribution of

consumption of NVP syrup, will be explained in detail under the fourth objective reviewed in this chapter.

From historical data presented in table 21, delivery time of NVP syrup at OMRMD indicates that 30% of the delivery times were within the prescribed time (one week) as stipulated in PSOP (65). This indicates that there is somehow an improvement in delivery times of stock from central medical store to OMRMD when compared to previous years, especially between 2010 and 2014 (30). This improvement was also confirmed by key informants who acknowledge punctual delivery compared to years prior to 2010. The remaining 70% of deliveries took more than the prescribed time (over 7 days) recording the longest delivery time of 55 days. This show that though there are some improvements regarding on time delivery, there is still room for improvement as 70% of the delivery time is over the prescribed time. This is supported by studies presented in the literature review regarding alternative strategies for distribution of pharmaceuticals to public-sector health facilities in Namibia (61). This 70% delay was also confirmed by majority key informants who raised a concern about long delivery time from CMS.

The findings from historical data (2012-2016), show that the descriptive statistics of delivery time of NVP syrup at OMRMD are positively skewed: as frequency decreases, delivery time increases in which shorter delivery times tend to be closer to the mean and longer delivery times tend to be further from the mean. Therefore, delivery-time distribution follows the exponential probability distribution. The exponential distribution is a special case of gamma distribution relative to the consumption of NVP syrup (118). Using the exponential probability distribution, a prediction of delivery-time delays can be calculated and preventative measures taken. The function of the exponential-probability

distribution model of delivery times is supported by optimising the ordering policy in supply chain, as was revealed by the study conducted in India (119, 120). Details of this model are explained in this chapter under the fourth objective.

From the findings, the average, mean-delivery time, 12 days, facilitates calculation of the stock of NVP syrup at OMRMD, serving health facilities in Oshana region. Twelve days help to ascertain the safety stock of NVP syrup at OMRMD. Calculated safety stock, based on a service level of 98%, was 266, 240-ml bottles, which is an adequate number for a maximum of 12 days. As explained previously (32), a 98% service level was chosen in accordance with ABC analysis, which directs that essential pharmaceutical items should have a service level between 95 and 98%. According to pharmaceutical standards, operational procedures (PSOP) dictate an ordering frequency of six weeks. However, data collected in the current study suggest an ordering frequency of seven weeks, corresponding to mean delivery time of 12 days. The calculated ordering frequency differs by one week ahead of the officially designated order frequency of six weeks (65). Many studies have shown that decreasing order frequency reduces the ordering cost, consequently improving the supply chain (121).

For the consumption of malaria rapid diagnostic test kit at OMRMD (C_m), presented in table 4.8, the mean consumption, or average monthly consumption, of mRDT at OMRMD is 2182 test kits or 87 packets at 25 kits per packet. The consumption of mRDT usually ranges from 0-740, which accounts for 30% of the total consumption. Figure 9 indicates that, as the consumption of mRDT shifts from the monthly average, the curve moves to the right. The more the OMRMD consumes (issues mRDT to health facilities) the less those health facilities order and receive mRDT. The chi-square goodness-of-fit-

test confirmed that distribution follows a gamma-probability distribution model, exactly the same as the model indicating consumption of NVP syrup at OMRMD (122). The model helps predict when a shortage will occur, hence facilitating measures to prevent stock-outs of mRDT. The gamma-probability distribution model has been used in many fields to predict fluctuation in various parameters (123). This study confirms that it is also a suitable, optimal mathematical model for the consumption of medicines at OMRMD. Details will be explained in detail under the fourth objective reviewed in this chapter.

The findings of the time-series analysis for consumption of mRDT at OMRMD between 2012 and 2016, indicate that seasonal fluctuations above and below mean consumption occur. Figure 8 shows there is always an increase of mRDT consumption between November and March, due to the appearance of mosquitoes during the rainy season, and consequentially the emergence of new cases of malaria (120). According to new malaria guidelines, every symptom of malaria should be tested with mRDT (91, 120). Qualitative findings, provided by interviews with key informants, confirm the increase of consumption of mRDT during the rainy season, explaining that health workers see a lot of malaria cases during this period. Some of the cases originate in Angola. It is thus obvious that health facilities need to order more mRDT during rainy seasons to meet demand.

Fluctuation in consumption of mRDT was also explained in a similar study conducted on time-series modeling and forecasting, where other determining factors were identified. Examples were the behaviour of patients and health workers regarding medication, environmental changes, poor recording systems and changes in malaria policy (115). Behaviour becomes a factor when, for example, patients demand to be tested for malaria

even when no symptoms of the disease are present. Also, the behaviour or attitudes of health workers can play a role, in so far as these influence responses among members of the community (68).

Delays in delivery of mRDT from CMS to OMRMD are indicated in figure 4.11, and apply to 37% of the delivery times, which lie between 16 and 23 days, with a mean delivery time of 22 days. This figure is more than twice the time expected for the delivery of pharmaceutical items. The findings also indicate that only 5% of deliveries complied with prescribed times. Even delays up to two months were noted. Delays were also admitted by key informants who said, “there are many delays in deliveries of pharmaceutical items, including mRDT.” One explanation given for those delays was the great distance between CMS, located in Windhoek, and OMRMD, a distance of more than 700 kilometres. Problems with transport vehicles only exacerbated the situation, some postulated. Most informants did not offer details on this subject, as they don’t deal with CMS. The distribution of delivery times of mRDT at OMRMD produces a standard probability distribution model. Using this model, OMRMD can predict when delays might occur and consequently how to prevent them. Details of the model are discussed under the fourth objective reviewed in this chapter.

Safety stock of mRDT at OMRMD was also calculated based on recorded data of replenishment times versus those required by PSOP (65). A safety stock of 166 packages of 25 mRDT was calculated, corresponding to a 15-day delivery time, with reorder frequency of seven weeks. The prescribed reorder frequency is six weeks. The implication of a seven-week reorder frequency, effectively a reduction in frequency of one week, is reduced costs. The explanation offered by this study, overall, smaller

inventories and lower costs resulting from reductions in transport time, produce a framework to understand the effects of transportation time on inventory (122).

Analysis of consumption levels at health centres was carried out by combining the statistics of all health centres, considering that the catchment population for each centre is roughly the same. This fact justified an assumption that consumption levels would also be roughly the same. Descriptive statistics of consumption of NVP syrup at HCs, indicated in table 16, show that the quantity of NVP syrup consumed lies generally in the range of 36 to 47, 240-ml bottles per month. This figure accounts for 37% of the consumption. The highest consumption is 107, 240-ml bottles (2%). This figure is greater than twice the average monthly consumption of NVP syrup at HCs, which is 42, 240-ml bottles. The graph of consumption against frequency, figure 13, shows that 58% of the consumption is within the monthly average consumption, hence the consumption distribution follows a normal-probability distribution model. The use of this model to predict consumption of the item was supported in the study and justified by the literature review (137). This model can also be incorporated in a gamma-probability distribution model, which is explained in the literature review (138, 139). These probability-distribution models, as models explained above, are important because they predict shortages of NVP syrup at HCs and therefore imply measures to prevent shortages and stock-outs. More details are discussed under objective four in this chapter.

The delivery time of NVP syrup at HCs (table 19) indicates that 55% of the delivery times are within the prescribed period (five working days to a week) as stipulated in SOP (65) with a mean delivery time of eight days. These findings are confirmed by qualitative input from key informants: “there is a lot of improvement when it comes to delivery

times compared to previous years." Forty-five percent (45%) of the times is beyond the prescribed delivery time, the long delivery times lying between 32 and 39 days, accounting for 3% of the delivery-time periods recorded. Delays in delivery are also explained in qualitative findings by key informants, who mention transport problems: more than five facilities served by a single driver, unavailability of vehicles and bureaucracy associated with registering vehicles to transport medicines.

Figure 13 shows that the distribution curve of delivery times conforms to a normal distribution model. This model has been used to describe delivery-time variations in many areas of business (126). More details are supplied under objective 4 of this chapter. Safety stock of NVP syrup at HCs was also calculated based on record data. Findings indicate that new stock should be ordered within two days after a minimum stock level has been reached. The reorder frequency is four weeks, or one month, a figure in line with the prescribed reorder frequency in PSOP (65).

Consumption of malaria rapid-diagnostic test kits at HCs (C_{hm}), indicated in table 23, shows that mean consumption, or average monthly consumption of mRDT at HCs, is 26 mRDT packages at 25 kits per package. Distribution of consumption of mRDT usually lies within the range from 0-740 kits which accounts for 30% of the total consumption. Figure 17 indicates that as the consumption of mRDT shifts from the monthly average, the curve moves to the right. By using chi-square goodness-of-fit test, the distribution was confirmed to conform to the Poisson probability-distribution model as in the consumption of NVP syrup above. This probability model helps predict shortages and therefore what measures may be appropriate to prevent stock-outs of mRDT.

Between 2012 and 2016 trends in consumption of NVP syrup at clinics fluctuated above and below the consumption mean with an accompanying seasonal trend as with OMRMD and health centres. Figure 4.31 indicates there is always an increase in mRDT consumption at clinics between November and March. As is relevant on other levels in the supply chain, this finding is explained by the rainy season in Namibia during this period which brings mosquitoes and therefore new cases of malaria. Every case exhibiting symptoms of malaria must be tested with mRDT (91, 120). Qualitative findings through key informants confirm increases in consumption of mRDT during rainy seasons by acknowledging that health workers see a lot of malaria cases during this period. Some cases are among Angolans. Thus, facilities need to order more mRDT during the rainy season in order to meet demand. The fluctuation in consumption was also explained in a similar study on time-series modeling and forecasting, where other factors causing fluctuation were identified, again pointing to behavior of patients regarding medication, poor recording systems and policy changes (115). Despite trend variations, there is a positive secular trend in consumption of mRDT at clinics which is shown in figure 4.32. This trend indicates that mRDT consumption at clinics is increasing over time. The substantial increase in the trend of consumption of mRDT (quantity of mRDT issued to clinics) between 2015 and 2016, as indicated in figure 4.32, was clearly due to implementation of the new malaria guideline of 2015, which prescribed testing for malaria in all cases of fever. As a result, these health facilities increase their orders of mRDT pushing up the consumption of mRDT at clinics.

Variations in time-series trends were smoothed in order to get a baseline, or CMA, as indicated in figure 4.32. The findings demonstrated that consumption in the second and

third quarters is below the baseline by 9% and 22%, respectively, while the fourth quarter is 44% above baseline consumption. Again, this trend is explained by the number of people returning to Ovamboland for holidays and the preparation of Mahangu fields. This influx motivates health centres and clinics to increase orders of mRDT from OMRMD. Consumption below baseline always occurs in winter. On the other hand, first-quarter consumption is in line with baseline consumption, explained by the fact that many people return to workplaces around the country. Also, considering that the rainy season occurs in the first quarter, more people in the region are expected to contract malaria. These findings are confirmed by the study conducted in Namibia to improve diagnoses and treatment of malaria in the country. Another study was conducted in Kenya regarding perceptions of malaria and acceptance of mRDT and related treatment practices among community members and health care providers in greater Garissa, North Eastern Province (124, 125). Seasonal fluctuations in the consumption of mRDT were also explained by informants who indicated that during the rainy and festival seasons, consumption tends to increase, beginning in November and ending in the beginning of January.

Delays in delivery of mRDT at the clinics from OMRMD, as indicated in figure 4., indicate that 27% of the reported delivery times were between 9 and 17 days, with a mean delivery time of 21 days, which is more than twice the prescribed time for delivery of pharmaceutical items. The findings also indicate that only 5% of delivery times were in line with prescribed delivery times. Delays up to nearly two months on mRDT deliveries were also recorded. Long delays in delivery were also explained qualitatively by key informants who said, “there are a lot of delays in delivery of pharmaceutical items, which include mRDT.” Two reasons given were the great distance between CMS,

located in Windhoek, and OMRMD, a distance of more than 700 kilometres, and problems associated with transport vehicles. Most of the informants did not give details because they don't work with CMS.

The distribution of delivery times produces a curve which conforms to a normal probability-distribution model. Using this model, a health facility can predict when delays will occur and therefore apply measures to prevent them. Details of the model are discussed under objective 4 in this chapter.

The distribution of delivery times conforms to a normal probability-distribution model. Using the model, a health facility can predict when times of delay might occur and therefore institute appropriate measures to prevent delays. Details of the model are discussed under objective 4 of this chapter.

Safety stock of mRDT at the clinics was calculated based on records of replenishment-time data compared with the replenishment time specified by PSOP (65). The safety stock of 166 packages, each containing 25 mRDT, corresponds to 15 days of delivery time, with a reorder frequency of seven weeks. Note that, the prescribed reorder frequency is six weeks. The implication of a seven-week reorder frequency, which is basically a reduction from six to seven weeks, produced lower costs, explained in the study by lower inventory levels and costs due to reduction in transport times, provide a framework for understanding the effects of transport time on inventory (122).

5.2.2 Factors associated with stock out of mRDT and NVP syrup

Different variables associated with stock out of mRDT at OMRMD, HC and clinics were considered by using Pearson coefficient correlation and binary logistic regression was

used to find out the variables which are statistically significant predict stock out of mRDT and NVP syrup. For variables associated with stock out of mRDT is illustrated by table 11 and 12 Delivery lead time, rainfall and temperature is statistically significant associated with stock out of mRDT at OMRMD. These findings were supported by informants who mentioned delayed of transport to deliver items on time. Also, some studies have shown that transportation of medicines has been a predictor of stock out of pharmaceutical items (5,6). At health centres and clinics, the findings show that average temperature and rainfall are associated with stock out of mRDT at HCs in the region. While in the clinics consumption and delivery lead time indicate as the variable associated with stock out of mRDT. Many informants from different levels of supply chain mentioned delivery lead time as one of the main cause of the stock out of mRDT at public health facilities. The other factors which were mentioned by informants is the irregular orders, however, the quantitative findings show the orders of mRDT is not statistically significant associated with stock out of mRDT. Experiences and other undocumented reports indicating that irregular ordering of medicines, including mart, especially at the clinic level where mostly pharmaceutical services is done by nurses who are not well knowledgeable in pharmaceutical skills. These qualitative findings are supported by different studies conducted in different countries regarding pharmaceutical knowledge among health care workers (94,112).

According to the quantitative findings, HIV incidence, HIV prevalence. and total prevalence are statistically significant associated with stock out of NVP syrup as illustrated in table 18, 19 and 20. Ordering of medicine was not statistically significant associated with stock out of NVP syrup, however informants in supply chain stated

“medicines, including NVP syrup are ordered randomly, which leads to overstock and expired medicines, this commonly occur at the clinic levels where nurses are very busy working as a pharmacist, meaning to take care of all pharmaceutical services and at the same time doing nurse work. Because of this reasons nurses are ordered randomly without following procedures as stated in Pharmaceutical Standard Operation Procedure (PSOP). OMRMD does not always confirm if the quantity ordered is what is actually needed. But most of the time we are assuming what is ordered by health facility that is what is required and if we have enough stock, then will issue based on what quantity needed” Though the order might not be inline with the consumption still OMRMD issued less than what HCs are requested, as some informants from OMRMD explained that “Sometimes we need to use common sense when we are issuing medicines to HCs, as we know it is difficult to store the large quantity of NVP syrup according to HCs orders. The reasons for inaccurate orders was firstly, quantitative achieved by examining the trends of ordering and receiving patterns/trends of NVP syrup and mRDT at health facilities and qualitatively by interviewing the key informants. Substantial increase in consumption of NVP syrup and mRDT at HCs and clinics is not a clear picture of consumption of those items, this is due to ordering behavior of health facilities. Large quantity of NVP syrup was issued to health facilities at some time which is four times the average monthly consumption of NVP syrup in all health facilities combined. This finding is supported by a district coordination committee (DCC) monthly report (30), as reported that, there is over consumption of medicine in Oshakati district. The findings also were explained by the informants from management level who said that ‘OMRMD do not know the consumption of medicines from facilities and most of the time we issue according to what

the health facility order. Most of the time quantity of medicines ordered by health facilities is entered into Syspro inventory control management software as they are, without doing any adjustment or communicate with that particular health facility which ordered the medicine. Informants from management level also narrated that, it can happen the health facility to order more quantity of medicines than the usual consumption because of misunderstanding of the unit of issue or sometimes overlook. The mistake can be identified during the process at OMRMD but poor communication and unknown consumption of NVP syrup at health facilities by OMRMD can leave a mistake unattended". Ordering and receiving trends of NVP syrup at HCs is not the same. There is a wider gap of about 89.3% as indicated in figure 15. This gap can be contributed to the ordering behavior of HCs where by staffs; most nurses are not well trained on ordering of pharmaceutical items. According to DCC(30), it has been reported that pharmaceutical items are ordered by guessing or assumption without following PSOP (65). As explained in qualitative findings that OMRMD received the order (quantity) and entered in the system as they are and most of the time no any adjustment to the order is done as OMRMD staffs are not aware of the consumption from the health facility.

Generally, it shows that delivery lead time has been a concern. Most of the time NVP syrup ordered by different health facilities delivered late beyond the prescribed time (65).This quantitative findings were corresponding to the qualitative findings which show that informants from different level of supply chain system, mentioned the problem of transport as a main cause of stock out of NVP syrup. "There is only one car which serve more than 4 health facilities and one driver. Sometimes you place emergence order but you will get it after a week. This makes the meaning of emergency order to be useless".

Among the factors which are associated with stock out rainfall, temperature and delivery lead time found to predict the stock out of mRDT as indicated in appendix 14. Using the factors predicts stock out of mRDT. For NVP syrup the predictors are shown in appendix 13, which are delivery lead time, HIV prevalence for pregnant mothers,

The ordering and receiving trend of mRDT at HCs show that there is a gap, meaning that the ordering trend and receiving trend are not the same; this is a similar situation in NVP syrup. Quantity of mRDT ordered is more than quantity received by 26% as shown in table 21. This is also supported by the findings shown in table 23, whereby negative values indicate quantity of mRDT received was not enough compares to what has requested and positive values show that OMRMD issued more of mRDT to HCs than requested. Ideally the trends of the quantity ordered and received should be the same if the demand of medicines is met by 100%. The finding is also supported by 100%, (n=17) informants who explained that, “It is not uncommon to receive a quantity of medicines less than what we order. This is not only for NVP syrup or mRDT but also for other medicines. From the finding as indicated in figure 21, the wider gap between quantity of mRDT ordered and received in HCs are mostly happened in quarter 1 and 2, this finding was elaborated qualitatively by more than 50% of key informants who pointed out that “ during the end of financial year when the medical stores are doing stock taking, there is a tendency of giving more medicines to other facility especially those which are short dated, so that to avoid ending up with expired items at the end of financial year”.

In the clinics, there is also the gap in trend of quantity ordered and received as in the other levels of the supply chain. But the findings at the level of the clinics show that the gap is much wider almost 89% of the NVP syrup ordered was not received. This is not

that the demand was not met as many key informants explained that in clinics there are no pharmacists or pharmacist assistants who are knowledgeable on ordering medicines according to PSOP (65). Nurses are just order medicine with guessing and assumption, this situation is worse in clinics compares to health centres. This finding is supported by a study done in Kenya on the assessment of the availability of medicine in Nairobi, county (123).

The predictor factors of stock out of NVP syrup and mRDT was determined using binary regression analysis. For the stock out of NVP syrup the finding show that delivery lead time was a predictor factor for the stock out of NVP syrup. The odds of stock out of NVP syrup occurring are defined as the ratio of the probability that stock out will occur to the probability that stock out will not as given by the equation. The ratio of the odds of stock out of NVP syrup when there is no constant and there is constant is 6.21 as indicated in the table 4.44. When the constant changes from not available to available the odds of stock out of NVP syrup is 6.21 times higher if all other variables, i.e., initial quantity, quantity of NVP syrup ordered from OMRMD, quantity received and closing stock stay the same.

In case of mRDT, the binary regression analysis indicates that the ordered quantity of mRDT by OMRMD from CMS is statistically significant predictor factor of stock out of mRDT with $p = 0.03$. The odds of stock out of mRDT occurring are defined as the ratio of the probability that stock out will occur to the probability that stock out will not as given by the equation. The ratio of the odds of stock out of mRDT when there is no quantity of mRDT ordered by OMRMD from CMS and there is quantity of mRDT ordered is 1.00. Constant is a significant predictor factor as mentioned already with an

Odd Ratio (OR) of 1. When the quantity of mRDT ordered by OMRMD from CMS changes from not available to available the odds of stock out of mRDT is 1 times higher if all other variables stay the same with the correct prediction rate of 93.3%. This finding is supported by the various literature which show that ordering of medicines can influence the stock out of medicines i.e., a health facility can order less than required ,hence run out of stock or order more and result to expiration and wastage (128). This quantitative finding was also supported by the findings from qualitative which show that more than 60% of the key informants from all levels of the supply chain said ‘ lack of proper knowledge of ordering from health facilities has resulted to the shortage and wastage of medicines”.

5.2.3 Development of Potential Model for Estimating Stock Levels

Historical data, known as a training data for five years were considered in order to develop different models at different health facilities. Table 11, 12 for mRDT and.22 and 23 for NVP syrup. The models developed do not allow stock out of NVP syrup and mRDT at health facilities by considering the service level of 96% - 98%. There are other factors which need to be considered for the good performance of the potential model developed. Apart from considering mRDT, rainfall and temperature should be put into considereation.when ordering mRDT,especially in ordering malaria rapid diagnostic test kit (mRDT). Different studies have shown the effects of rainfall and temperature in the rise of malaria incidence. Rainfall aids in accumulation of stagnant water, hence making the environment ideal for mosquito breeding sites, whereas, higher temperatures accelerate parasitic plasmodium growth within mosquitoes and make the mosquitoes active (58, 59). There is no optimal model of stock level which is hundred percent correct

(127,139,141). The models developed considered average delivery lead time at different health facilities and average daily demand of NVP syrup and mRDT at different health facilities. Optimal supply chain model of NVP syrup at OMRMD indicated that, reorder quantity of 435 B/240ml of NVP syrup is sufficiently enough to meet the demand of NVP syrup at health centres and clinics. The procurement frequency is 7 weeks, this is different from by 1 week, from the prescribe procurement period of 6 weeks (65). There is advantage of 7 weeks procurement period compares to 6 weeks procurement period. The studies show that the shorter reorder frequency the higher the cost, hence seven weeks is less costly compares to 6 weeks (19). In health centres , the optimal supply chain model of NVP syrup showed that in order to meet the demand of NVP syrup the reorder quantity should be 164 B/240ml with the procurement frequency of 4 weeks or 1 month. The procurement frequency proposed by this model is exactly the same as that prescribes in PSOP (65). The optimal supply chain model developed for HC considered that all HCs have the same storage capacity and consumption is the same to all HC. However, this is not the case. The supply chain model of NVP syrup at the clinics indicated that in order to meet the demand of NVP syrup and prevent the stock out, reorder quantity should be 116 B/240ml of NVP syrup with the procurement period of 4 weeks or 1 month. The procurement period prescribed in PSOP is also 4 weeks. This optimal model work effectively to all clinics in Oshana region, provided that all the clinics have the same demand and storage capacity is the same.

In case of malaria diagnostic rapid test kit, the optimal supply chain model at OMRMD indicated that reorder quantity is 183 P/25 with seven weeks as the procurement period . As stated above the current procurement period at OMRMD is six weeks which is less for

1 week as proposed in this model. As explained above advantage of seven weeks as reorder frequency is that it will reduce, cost. The shorter the reorder frequency the higher the cost, hover it works effectively if the storage is sufficient enough.(97). For health centres the proposed optimal model of mRDT, show that in order to meet the demand of mRDT and prevent stock out by 96% at health centres, a total 25 P/25 should be ordered at every 4 weeks. This 4 weeks have also prescribed in PSOP. For clinics, in order to meet the demand, the total of 9 P/25 of mRDT should be ordered at the frequency period of 4 weeks. There is no clear explanation on why the reorder frequency at the clinics is higher compares to that of the health centres. Perhaps is due to challenge of supply chain, especially poor documentation and irregular ordering as stated by informants.

5.2.4 Simulation and validation of Potential Models

Simulation is the process of designing a model of a real system and conducting experiment with the model for the purpose of understanding the behavior of the operation of a system. (123). The simulation was carried out, simply because it is cheap and take a short period of time to do it, rather than going to the site and conduct evaluation which is time consuming and logistic to do it is a bit complicated. The simulation done in this study mimic exactly the supply chain system practiced at different health facilities in Oshana region. Several studies (124,125) have shown that, simulation techniques are very useful in the evaluation of inventory control. In this study Monte Carlo simulation technique in SPSS was used to assess the performance or the impact of the optimal mathematical supply chain models at the next fourth months in the real world event. It deals with taking random samples from the distribution of consumption of NVP syrup and mRDT in order to supplies series of values for use in the model.(126). Different

literatures indicate that the performance of a proposed model should be more than 50% of the simulated model to be accepted as a good model (125-130). In this study basically models simulation were illustrated by table 13 , 14 and 22 and 23.The steps are establishing probability distribution of NVP syrup and mRDT, cumulative probability distribution, setting random number intervals, generating random numbers and compare the simulated reorder quantity and the reorder quantity of the training data. Out of time data validation, which means the predicted out of data in 2012-2016 was used, in this case four months data in 2017 was used to validate the models. Simulated demand and delivery lead time of NVP syrup at Oshakati Multi Regional Medical Depot (OMRMD) is shown in table 22 and 23 respectively was calculated and reorder quantity was determined from simulated data based on the formula which states that ROP of NVP syrup at OMRMD is equal to daily demand of NVP syrup times delivery lead time plus safety stock. The same procedure to calculate ROP was done for health centres and the clinics for both pharmaceutical items, that is NVP syrup and mRDT as shown in table 13, 14.

$ROPnvp_{OMRMD}$ simulated was comparing with the $ROPnvp_{OMRMD}$ calculated from the historical data by finding the percentage in order to check how well the model will perform in preventing stock out of NVP syrup and mRDT at health facilities. Optimal supply chain models of NVP syrup at OMRMD indicated the performance of 94% which is quite good compares to the similar study done in India and Nigeria, which show the performance of 65% (134,136-140) Optimal model of NVP syrup at HC indicate that the optima reorder point is 71% while at the clinics the performance is 73% which is also good compares to other similar study done in different country like Tanzania (55) Overall

the optimal supply chain model of NVP syrup at different health facilities is accuracy by more than 70%. The validation of optimal model of mRDT shows that Reorder point(ROP) of mRDT at Oshakati MultiRegional Medical Depot(OMRMD), health centres and clinics is accuracy by 98.6%,73.3% and 81.6% respectively. Different studies indicated that simulated models to be valid should at least have a performance rate of more than 50% (131,141)

5.3 Conclusion

This study gave an account of the use of a gold standard in controlling stock levels compared to the current one which does not consider the seasonality and irregularities due to different factors. As stated in the introductory part of this study the purpose was to develop a gold standard method which is a mathematical method to prevent stock out of NVP syrup and mRDT in public health facilities in Oshana region by checking the historical consumption rates for the period of 5 years, factors which is associated with stock-out and then development of the model.

The findings indicates that in every quarter the consumption of mRDT increases by 289 kits which is equivalent 12 P/25 at OMRMD, while at health centres the consumption increases by 6P/25 in each quarter and at the clinics the consumption increases by 2 P/25 in every quarter. The model was validated by simulation technique using Monte Carlo. The first part of the study was malaria test kit, the conclusion drawn from this part is that OMRMD should order 183 P/25 kits which is optimally sufficient to prevent stock out by 98% at health centres and clinics in Oshana region. Order of mRDT at OMRMD should be 183 P/25 kits in every seven weeks.

The first part of malaria test kit. developed will significantly reduce stock out of NVP syrup and mRDT by considering the daily demand, lead time and safety stock. As the findings from this study the reorder quantity and ordering frequency proposed in the model can significantly satisfy the demand by reducing the stock out between 96-98%, by predicting the demand and eventually to prevent stock out by taking necessary measures. However, other factors need to put into consideration, this includes temperature, rainfall and orders from health facilities to OMRMD .The models herein developed was founded

on real-life scenarios, unlike studies referenced in the literature. As a result of this finding, the study proposes reorder level and reorder frequency to be applied. The results demonstrate that the implementation of optimal mathematical supply-chain model can significantly reduce stock out within the supply-chain system, consequently improving the chain's overall performance. In this study it is indicated that, quantity of pharmaceutical items (NVP syrup and mRDT) issued to health facilities from OMRMD is statistically associated with stock out of NVP syrup and mRDT while weather such as rainfall and temperature are marginal statistically associated with the stock out of malaria rapid diagnostic test kit. Informants pointed out that many irregularities exist in terms of ordering, documentation and consumption of medicine including NVP syrup and mRDT. Training is needed in order to address improper ordering hence to reduce stock out. However, it was also recommended that extratemporenous preparation can be done in case of a completely stock out of nevirapine syrup.

The problem statement, the aim and specific objectives outlined in the study were supported by a comprehensive review of existing literature, which included a brief historical record on the supply chains of essential medicines. A research methodology, based on a mixed method, was selected for the study. The data gathered and analysed, as well as resulting findings with reference to appropriate literature, was also discussed. The over-arching conclusion reached by the study was, that the optimal mathematical supply-chain model developed in the study is useful to predict, and thus help prevent, stock-outs.

The study recommends that the use of the optimal mathematical supply-chain model and appropriate documentation of consumption, including its distribution to other departments within the health sector, is crucial to improve the supply-chain system and

therefore prevent stock-outs of Malaria Diagnostic test kit and nevirapine syrup. The use of this supply models will curb unnecessary costs due to irregular orders. Furthermore, the model will contribute to the prevention of stock out and diseases control.

5.4 Recommendations.

5.4.1 The Use of Potential Model

This study has revealed that a limited capacity exists in the forecasting and quantification of data in the health sector in Oshana region. A systematic, optimal mathematical model based on daily demand and average lead time would be an effective way to address the problem of common stock-outs of mRDT and NVP syrup. A logical system would help healthcare personnel who work in the supply chain to manage stock levels according to the model.

5.4.2 Testing of the Model in a larger scale.

Using Monte Carlo simulation techniques shows that, the model is good in controlling stock levels of mRDT and NVP syrup in public health facilities, however there is a need to test the model in larger scale e.g. at the national level. Additionally, it is recommended that similar models should be developed for other medicines such as anti TB, other ARVs and antihypertensive drugs.

5.4.3 Policy change

There is a need to improve the Pharmaceutical Standard Operation Procedure in terms of procurement frequency. The findings from this study, indicates that ordering frequency at

Oshakati Multi Regional Medical Store is 7 weeks. The one prescribes in PSOP is 6 weeks. The shorter the procurement frequency the higher the cost (131)

5.4.4 Transparency in Supply-Chain Procurement

The transparency of procurement laws in the medical context and other activities in the system should be promoted and spread to personnel involved in the supply chain at all levels, and not be privileged information accessible to some in central positions in the chain as is currently practiced. Transparency should include widespread distribution of information regarding budget allocations. Several informants addressed in the study pointed out that some members at supply points order stock irresponsibly because they are not held accountable to budgetary considerations. Establishment of a system whereby all healthcare personnel can be monitored in the context of budgetary constraints will increase responsibility for their actions.

Systems of reporting and sharing information among departments in the supply chain need to be strengthened. The findings in this study revealed the absence of a proper reporting system regarding the consumption of medicines (mRDT and NVP syrup). The actual consumption of these medicines is reported by nurses to PHC supervisors through monthly, week-surveillance reports for malaria and baby-to-mother follow-up reports for NVP syrup. These reports are an excellent source of information regarding actual consumption data. However, pharmacists responsible to order those medicines do not have access to the reports. Key medical personnel monitoring malaria and HIV cases should be instructed to submit the reports to pharmacy personnel so that an effective overview concerning quantification and forecasting can be maintained.

5.4.4 Trained Staff for Inventory Management and Logistics

Shortage and adequately trained staff for the management of the supply-chain system is not provided. Clinics are managed by nurses. These nurses are also responsible for interaction with pharmaceutical personnel at the clinic. However, nurses have not received training on the management of pharmaceutical services to function in this capacity without assistance. The situation creates a vacuum in the efficient functioning of the supply chain. If nurses cannot be trained, legislative provision for the recruitment of additional pharmacist personnel at all levels should be made. Additionally, where a post for a pharmacist or pharmacist assistant is not provided, nurses stationed in those facilities should at least be trained in inventory management and logistics.

5.4.5 Further Studies

This study has made important findings concerning the current stock levels of mRDT and NVP syrup and the beneficial influence that a mathematical model of stock levels can exercise on its efficiency.

Further studies that would examine conditions of stock levels at all levels of supply chain , from national down to the local, where most of the stakeholders in the supply chain operate, should address costing functions, to include holding costs and ordering costs, throughout the hierarchy. These two cost factors are very important to the efficient management of inventory, and their routine identification an important factor in the operation of the overall supply-chain system for the prevention of stock-outs of medicines. Unfortunately, these two parameters are not adequately understood in public-health facilities. Systematic distribution of information concerning their influence would create a broader picture of the medical supply chain in the whole country and would

eventually lead to the development of an optimal, mathematical model that would be relevant at the highest possible levels and take into consideration even more parameters in the system.

5.2 Summary

In this chapter analysis and findings were made both from quantitative and qualitative parts. The results answered the research questions and revealed the importance of optimal mathematical supply chain models based on the past record of medicines consumption. Details of the interpretation of the findings are discussed in chapter 5. Quantitative findings were evaluated in detail to reveal how the optimal mathematical supply-chain model can be applied to predict the occurrence of stock-outs. Factors associated with stock-outs were also identified using the binary-regression method. Qualitative findings, complementing quantitative results, also provided a broader picture of the supply chain and a clearer representation of the challenges facing its functioning in Oshana region. Simulated data were inserted to evaluate the effectiveness and the impact of the supply-chain model in terms of reorder levels. Quantitative and qualitative findings were compared with the findings of similar studies conducted in other countries. Limitations and weaknesses in the study were also presented, indicating clearly the need for further research.

5.3 Limitations of the Study

The study conducted in Oshana region only, therefore the selection, procurement, distribution and regulations of mRDT and NVP syrup at the national level were excluded. These limitations are due to financial constraints and limited time available for conducting this study.

The study interviewed only players in the supply chain at the regional level who may not have a proper information on the issues of tenders, procurement, regulations related to mRDT and NVP syrup. Other informants who were not interviewed were donors or

funders of the program from the national level, the ministry of finance and end users who are the patients. These players in the supply chain could increase more deeper understanding of the supply chain and the challenges of the supply chain system at all levels in the country.

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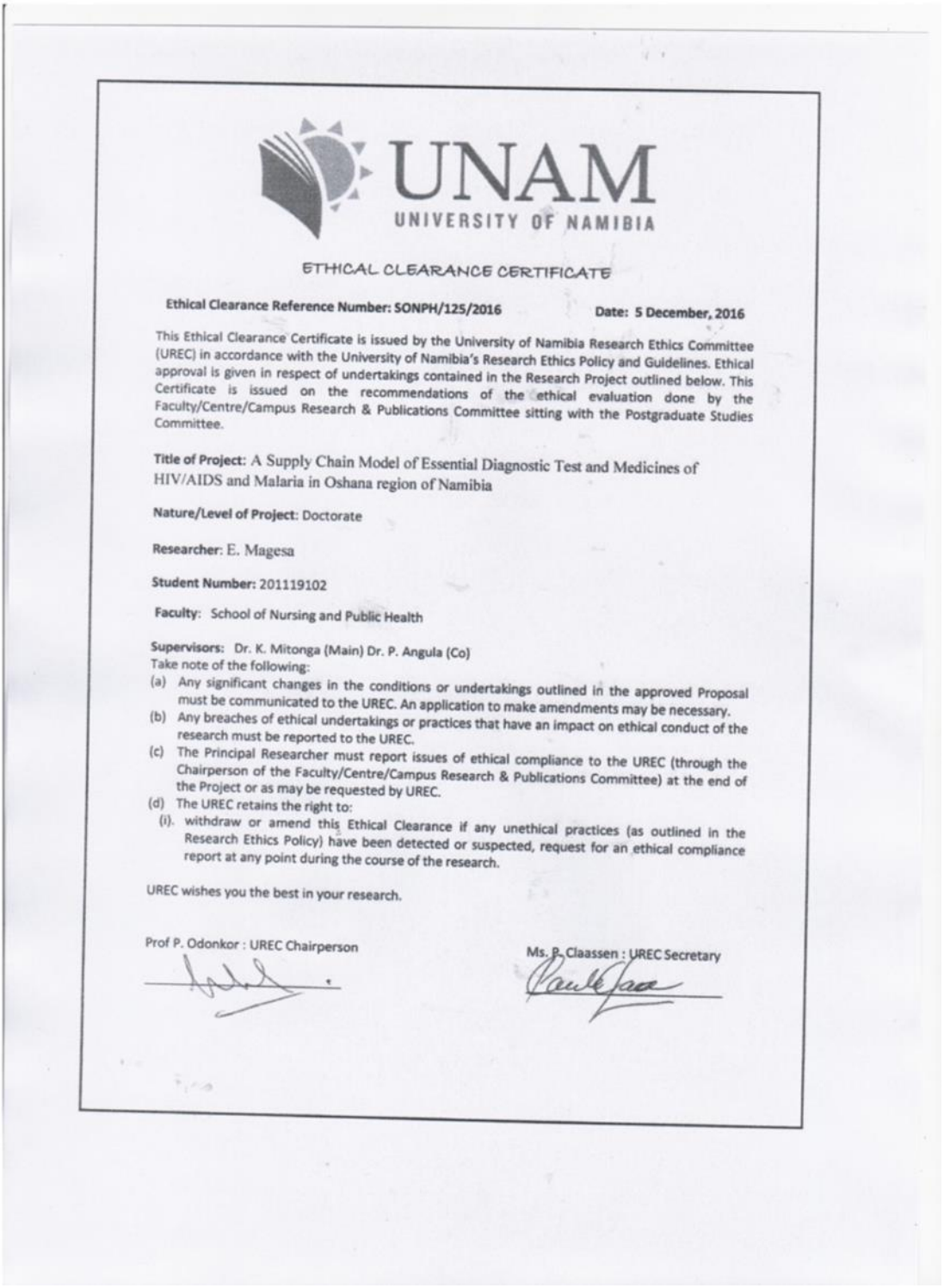
APPENDICES

Appendix 1: Ethical clearance from University of Namibia(UNAM)



UNAM
UNIVERSITY OF NAMIBIA

ETHICAL CLEARANCE CERTIFICATE

Ethical Clearance Reference Number: SONPH/125/2016 **Date: 5 December, 2016**

This Ethical Clearance Certificate is issued by the University of Namibia Research Ethics Committee (UREC) in accordance with the University of Namibia's Research Ethics Policy and Guidelines. Ethical approval is given in respect of undertakings contained in the Research Project outlined below. This Certificate is issued on the recommendations of the ethical evaluation done by the Faculty/Centre/Campus Research & Publications Committee sitting with the Postgraduate Studies Committee.

Title of Project: A Supply Chain Model of Essential Diagnostic Test and Medicines of HIV/AIDS and Malaria in Oshana region of Namibia

Nature/Level of Project: Doctorate

Researcher: E. Magesa

Student Number: 201119102

Faculty: School of Nursing and Public Health

Supervisors: Dr. K. Mitonga (Main) Dr. P. Angula (Co)

Take note of the following:

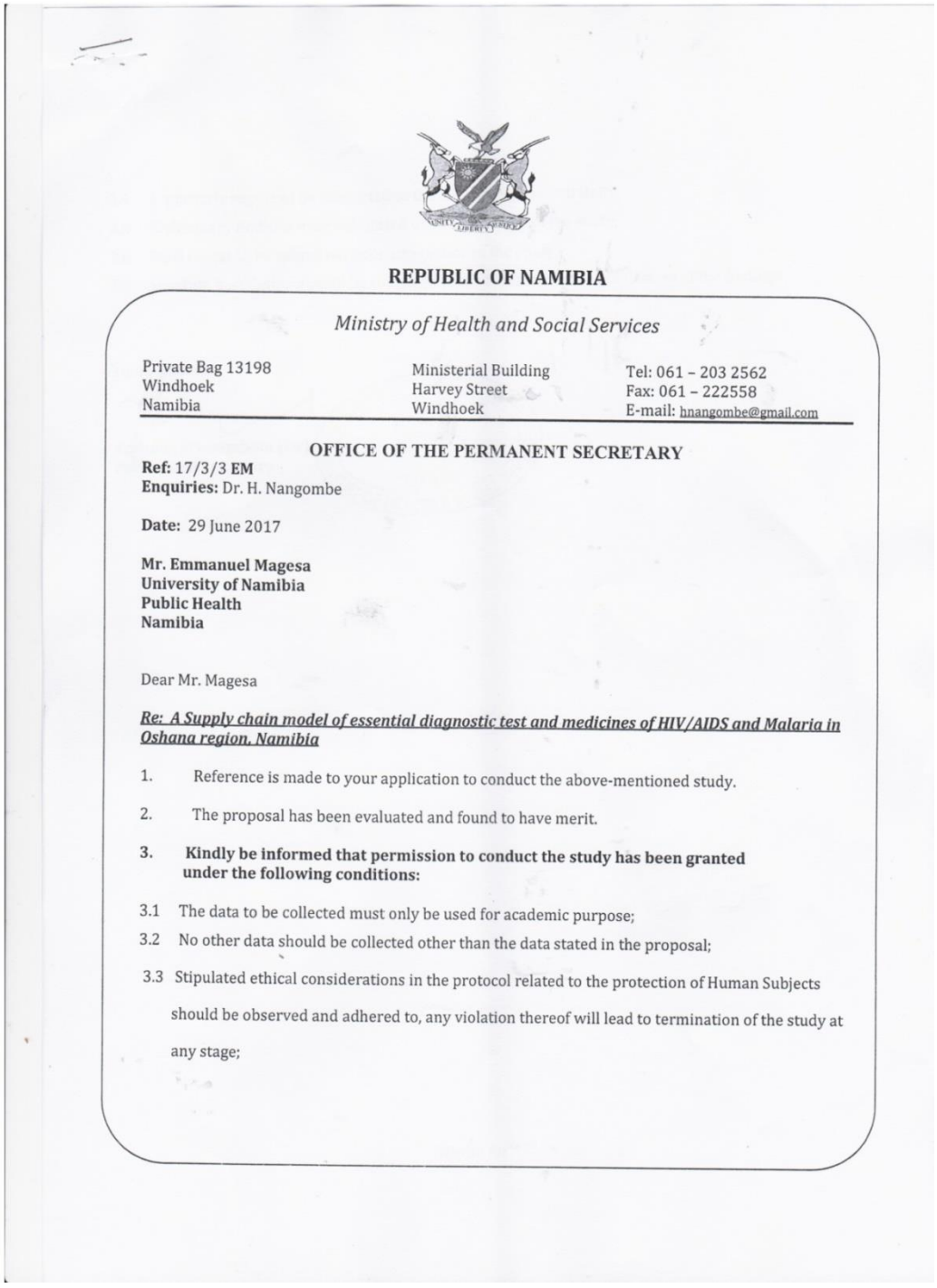
(a) Any significant changes in the conditions or undertakings outlined in the approved Proposal must be communicated to the UREC. An application to make amendments may be necessary.
(b) Any breaches of ethical undertakings or practices that have an impact on ethical conduct of the research must be reported to the UREC.
(c) The Principal Researcher must report issues of ethical compliance to the UREC (through the Chairperson of the Faculty/Centre/Campus Research & Publications Committee) at the end of the Project or as may be requested by UREC.
(d) The UREC retains the right to:
(i). withdraw or amend this Ethical Clearance if any unethical practices (as outlined in the Research Ethics Policy) have been detected or suspected, request for an ethical compliance report at any point during the course of the research.

UREC wishes you the best in your research.

Prof P. Odonkor : UREC Chairperson

Ms. P. Claassen : UREC Secretary

Appendix 2: Permission letter from Ministry of health and social services to conduct research.



REPUBLIC OF NAMIBIA

Ministry of Health and Social Services

Private Bag 13198
Windhoek
Namibia

Ministerial Building
Harvey Street
Windhoek

Tel: 061 – 203 2562
Fax: 061 – 222558
E-mail: hnangombe@gmail.com

OFFICE OF THE PERMANENT SECRETARY

Ref: 17/3/3 **EM**
Enquiries: Dr. H. Nangombe

Date: 29 June 2017

Mr. Emmanuel Magesa
University of Namibia
Public Health
Namibia

Dear Mr. Magesa

Re: A Supply chain model of essential diagnostic test and medicines of HIV/AIDS and Malaria in Oshana region, Namibia

1. Reference is made to your application to conduct the above-mentioned study.

2. The proposal has been evaluated and found to have merit.

3. **Kindly be informed that permission to conduct the study has been granted under the following conditions:**

3.1 The data to be collected must only be used for academic purpose;

3.2 No other data should be collected other than the data stated in the proposal;

3.3 Stipulated ethical considerations in the protocol related to the protection of Human Subjects should be observed and adhered to, any violation thereof will lead to termination of the study at any stage;

3.4 A quarterly report to be submitted to the Ministry's Research Unit;

3.5 Preliminary findings to be submitted upon completion of the study;

3.6 Final report to be submitted upon completion of the study;

3.7 Separate permission should be sought from the Ministry for the publication of the findings.

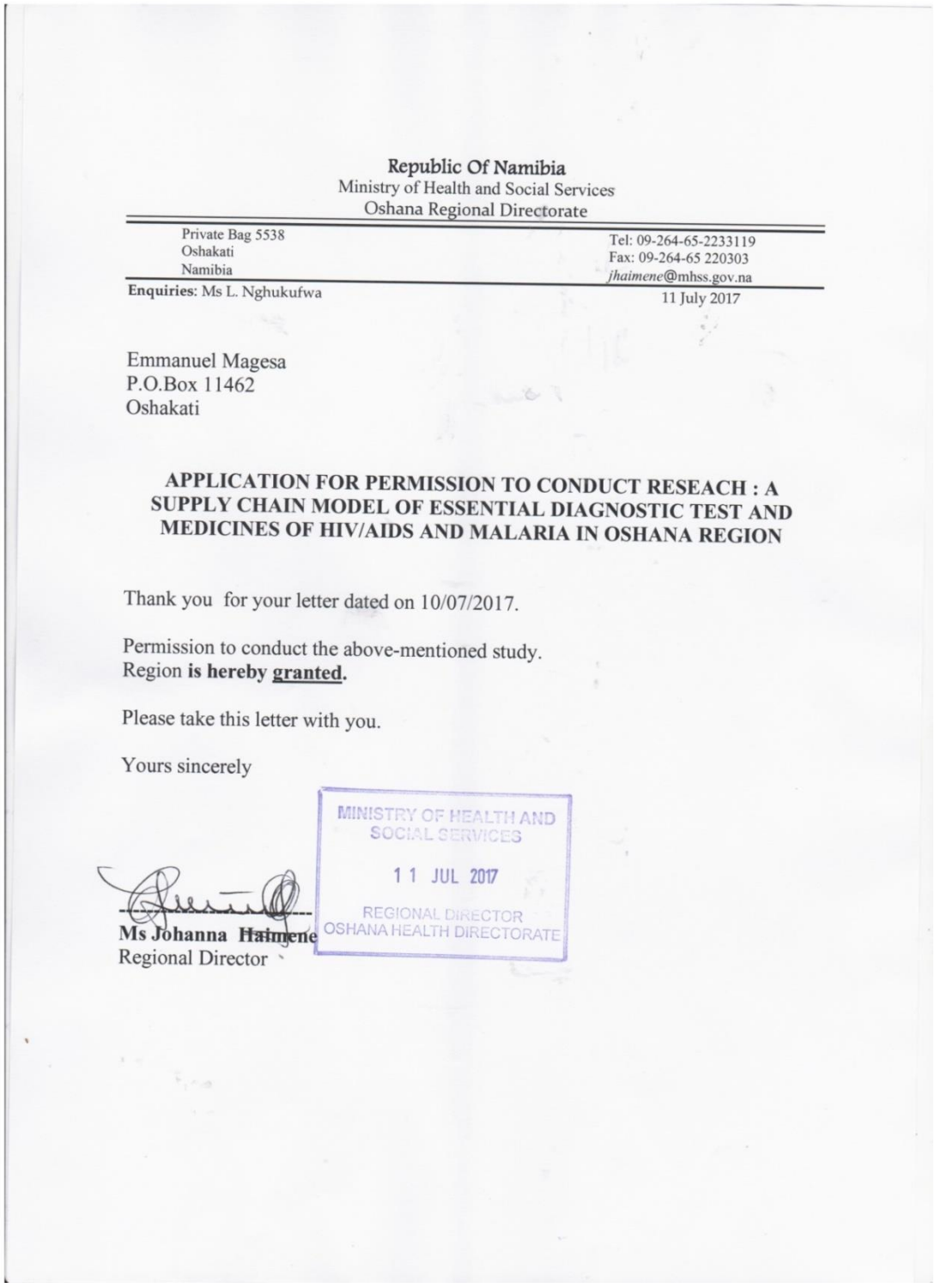
Yours sincerely,

Andreas Mwoombola (Dr)
Permanent Secretary

PERMANENT SECRETARY
MINISTRY OF HEALTH & SOCIAL SERVICES

"Health for All"

Appendix 3: Permission letter from Oshana health directorate.



Republic Of Namibia
Ministry of Health and Social Services
Oshana Regional Directorate

Private Bag 5538
Oshakati
Namibia

Tel: 09-264-65-2233119
Fax: 09-264-65 220303
jhaimene@mhss.gov.na

Enquiries: Ms L. Nghukufwa

11 July 2017

Emmanuel Magesa
P.O.Box 11462
Oshakati

APPLICATION FOR PERMISSION TO CONDUCT RESEACH : A SUPPLY CHAIN MODEL OF ESSENTIAL DIAGNOSTIC TEST AND MEDICINES OF HIV/AIDS AND MALARIA IN OSHANA REGION

Thank you for your letter dated on 10/07/2017.

Permission to conduct the above-mentioned study.
Region **is hereby granted.**

Please take this letter with you.

Yours sincerely

MINISTRY OF HEALTH AND SOCIAL SERVICES
11 JUL 2017
REGIONAL DIRECTOR
OSHANA HEALTH DIRECTORATE

Ms Johanna Haimene
Regional Director

Appendix 4: Consent form

UNIVERSITY OF NAMIBIA

SCHOOL OF PUBLIC HEALTH

INFORMED CONSENT FORM FOR HEALTH PROFESSIONAL AND NON HEALTH PROFESSIONAL WHO ARE WORKING DIRECTLY OR INDIRECTLY IN SUPPLY CHAIN OF ESSENTIAL MEDICINES AND DIAGNOSTIC TEST FOR HIV/AIDS, MALARIA IN OSHANA REGION

This Informed Consent Form has two parts:

• Information Sheet (to share information about the study with you)

• Certificate of Consent (for signatures if you choose to participate)

You will be given a copy of the full Informed Consent Form

Part I: Information Sheet

Introduction

I am EMMANUEL MAGESA, a PHD student at the University of Namibia. I am doing research on the supply chain model of essential medicines and diagnostic test kits for HIV/AIDS and Malaria.These diseases(HIV/AIDS and Malaria diseases are very common in this country and in this region and also the shortage of medicines to prevent and treat HIV/IDS and malaria. I am going to give you information and invite you to be part of this research. You do not have to decide today whether or not you will participate in the research. Before you decide, you can talk to anyone you feel comfortable with about the research.

This consent form may contain words that you do not understand. Please ask me to stop as we go through the information and I will take time to explain. If you have questions later, you can ask me

Purpose of the research

Shortage/stock out of medicines and diagnostic test kit for HIV/AIDS and Malaria result in compromising access to effective treatment, sub optimal case management practices and increase mortality. We want to find ways to stop this from happening. I believe that you can help by telling us what you know both about the shortage of HIV/AIDS and malaria medicines and about supply chain practices in general. We want to learn what health professional and non health professional who involve in the supply chain of medicines and diagnostic test kit of HIV/AIDS and Malaria know about the causes of

shortage of medicines and why. We want to learn about the different ways that try to stop/prevent stockout/shortage of medicines. We also want to know more about supply chain practices because this knowledge might help us to learn how to better prevent stockout by developing a new supply chain model.

Type of Research Intervention

This research will involve your participation in an unstructured interview that will take about one and a half hours

Participant Selection

You are being invited to take part in this research because we feel that your experience in the supply chain can contribute much to our understanding and knowledge of supply chain practices in the region

Voluntary Participation

Your participation in this research is entirely voluntary. It is your choice whether to participate or not. The choice that you make will have no bearing on your job or on any work-related evaluations or reports. You may change your mind later and stop participating even if you agreed earlier.

Procedures

We are asking you to help us learn more about supply chain in this region. We are inviting you to take part in this research project. If you accept, you will be participating in an interview with myself.

During the interview, I will sit down with you in a comfortable place at your workplace. If you do not wish to answer any of the questions during the interview, you may say so and the interviewer will move on to the next question. No one else but the interviewer will be present unless you would like someone else to be there. The information recorded is confidential, and no one else except EMMANUEL MAGESA will access to the information documented during your interview. The entire interview will be tape-recorded, but no-one will be identified by name on the tape. The tape will be kept in a safe and secured place. The information recorded is confidential, and no one else except EMMANUEL MAGESA, DR.PENEHAFO ANGULA AND DR. MITINGA will have access to the tapes. The tapes will be destroyed after completion of data analysis.

Duration

The research might visit you several times for an interview if he feels there is a need to get more information or clarity on some issues.

Risks

There is a risk that you may share some personal or confidential information by chance, or that you may feel uncomfortable talking about some of the topics. However, we do not wish for this to happen. You do not have to answer any question or take part in the discussion/interview/survey if you feel the question(s) are too personal or if talking about them makes you uncomfortable.)

Benefits

There will be no direct benefit to you, but your participation is likely to help us find out more about how to prevent stockout in the region.

Confidentiality

We will not be sharing information about you to anyone outside of the research team. The information that we collect from this study will be kept private. Any information about you will have a number on it instead of your name. Only the researchers will know what your number is and we will lock that information up with a lock and key. It will not be shared with or given to anyone except University of Namibia and Ministry of health and social services

Sharing the Results

Nothing that you tell us today will be shared with anybody outside the research team, and nothing will be attributed to you by name. The knowledge that we get from this research will be shared with you and your region before it is made widely available to the public. Each informants will receive a summary of the results. There will also be small meetings in the region and these will be announced. Following the meetings, we will publish the results so that other interested people may learn from the research.

Right to Refuse or Withdraw

You do not have to take part in this research if you do not wish to do so, and choosing to participate will not affect your job or job-related evaluations in any way. You may stop participating in the interview at any time that you wish without your job being affected. I will give you an opportunity at the end of the interview to review your remarks, and you can ask to modify or remove portions of those, if you do not agree with my notes or if I did not understand you correctly.

Who to Contact

You can ask me any more questions about any part of the research study, if you wish to. Do you have any questions?

Part II: Certificate of Consent

I have read the foregoing information, or it has been read to me. I have had the opportunity to ask questions about it and any questions I have been asked have been answered to my satisfaction. I consent voluntarily to be a participant in this study

Print Name of Participant_____

Signature of Participant _____

Date _____

Day/month/year

A statement by the researcher/person taking consent

I have accurately read out the information sheet to the potential participant, and to the best of my ability made sure that the participant understands that the following will be done:

1.

2.

3.

I confirm that the participant was given an opportunity to ask questions about the study, and all the questions asked by the participant have been answered correctly and to the best of my ability. I confirm that the individual has not been coerced into giving consent, and the consent has been given freely and voluntarily.

A copy of this ICF has been provided to the participant.

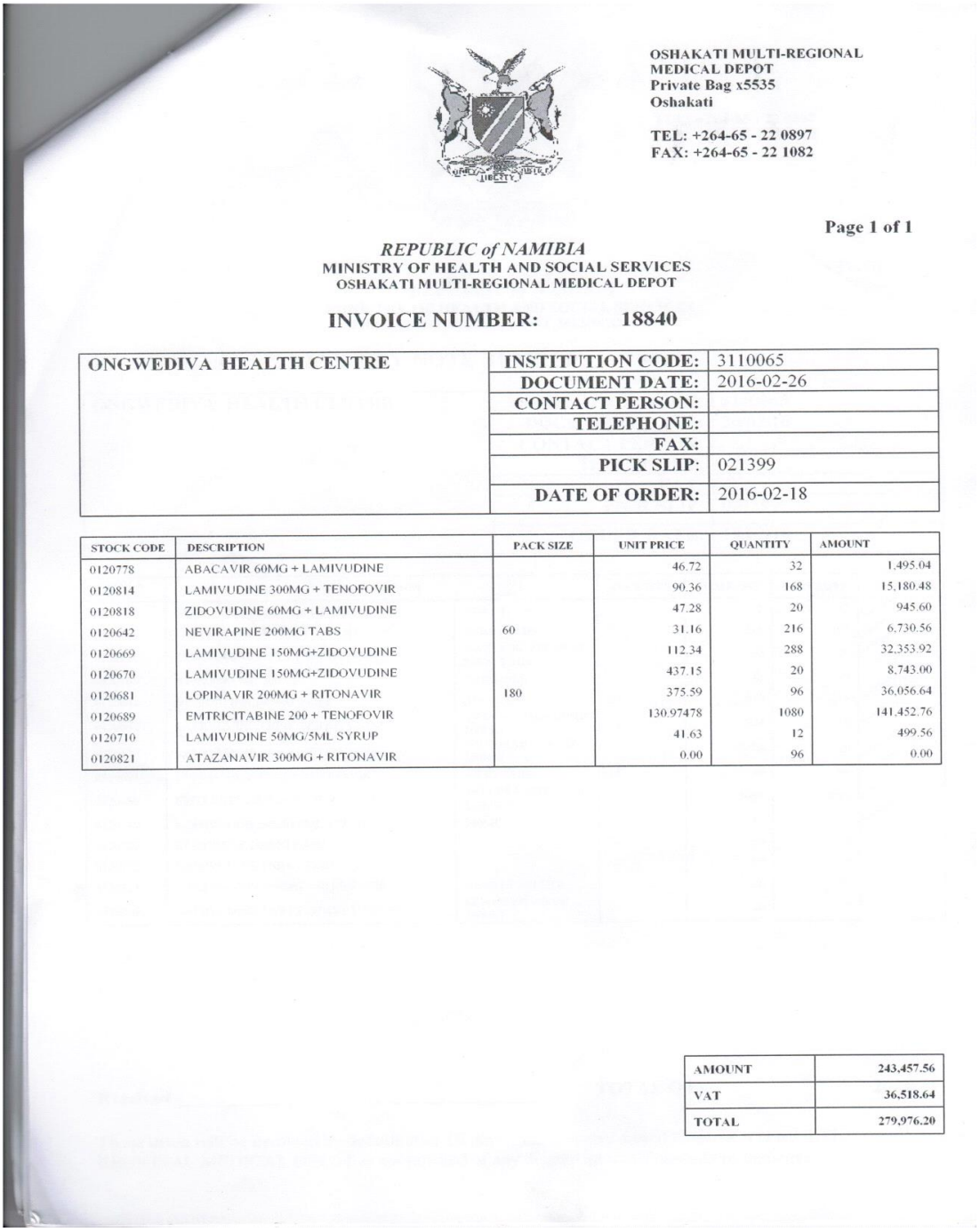
Print Name of Researcher/person taking the consent_____

Signature of Researcher /person taking the consent_____

Date _____

Day/month/year

Appendix 5: Invoice for identification of unit price



OSHAKATI MULTI-REGIONAL
MEDICAL DEPOT
Private Bag x5535
Oshakati

TEL: +264-65 - 22 0897
FAX: +264-65 - 22 1082

Page 1 of 1

REPUBLIC of NAMIBIA
MINISTRY OF HEALTH AND SOCIAL SERVICES
OSHAKATI MULTI-REGIONAL MEDICAL DEPOT

INVOICE NUMBER: 18840

ONGWEDIVA HEALTH CENTRE		
	INSTITUTION CODE:	3110065
	DOCUMENT DATE:	2016-02-26
	CONTACT PERSON:	
	TELEPHONE:	
	FAX:	
	PICK SLIP:	021399
	DATE OF ORDER:	2016-02-18

STOCK CODE	DESCRIPTION	PACK SIZE	UNIT PRICE	QUANTITY	AMOUNT
0120778	ABACAVIR 60MG + LAMIVUDINE		46.72	32	1,495.04
0120814	LAMIVUDINE 300MG + TENOFOVIR		90.36	168	15,180.48
0120818	ZIDOVUDINE 60MG + LAMIVUDINE		47.28	20	945.60
0120642	NEVIRAPINE 200MG TABS	60	31.16	216	6,730.56
0120669	LAMIVUDINE 150MG+ZIDOVUDINE		112.34	288	32,353.92
0120670	LAMIVUDINE 150MG+ZIDOVUDINE		437.15	20	8,743.00
0120681	LOPINAVIR 200MG + RITONAVIR	180	375.59	96	36,056.64
0120689	EMTRICITABINE 200 + TENOFOVIR		130.97478	1080	141,452.76
0120710	LAMIVUDINE 50MG/5ML SYRUP		41.63	12	499.56
0120821	ATAZANAVIR 300MG + RITONAVIR		0.00	96	0.00

AMOUNT	243,457.56
VAT	36,518.64
TOTAL	279,976.20

Appendix 6: Checklist

Year	Month	Initial stock	Qty ordered by RMS from CMS	Qty received by RMS	Qty ordered by HFs from RMS	Qty issued to HFs	Closing stock	Duration	Transport	Storage	Expired Qty
2012											

Appendix 7: Dataset of NVP syrup from health facility.

Month/ye		Facility name	Description	Initial stock	OrderQty	Received Qty	Consumptio	Final closi	Unit price for quantity received	Estimated storing cost	Estimated transp	Expired qua	Cost of expired quantity(N$	Difference (order -recei	duration
2012	1	2	NVP SUSP	0	4	3	1	2	383.76		420	0	0	1	5
	2	2	NVP SUSP	2	6	5	2	5	639.6		420	5	639.6	1	7
	3	2	NVP SUSP	0	6	6	0	6	767.52		420	0	0	0	9
	4	2	NVP SUSP	6	7	6	2	10	767.52		420	0	0	1	10
	5	2	NVP SUSP	10	4	4	3	11	511.68		420	0	0	0	12
	6	2	NVP SUSP	11	6	6	0	17	767.52		420	0	0	0	3
	7	2	NVP SUSP	17	1	0	2	15	0		420	0	0	1	8
	8	2	NVP SUSP	15	0	0	0	15	0		0	0	0	0	
	9	2	NVP SUSP	15	13	13	1	27	1662.96		420	0	0	0	4
	10	2	NVP SUSP	27	0	0	2	25	0		0	0	0	0	0
	11	2	NVP SUSP	25	0	0	0	25	0		0	20	2558.4	0	
	12	2	NVP SUSP	5	11	11	2	14	1407.12		535	0	0	0	
2013	1	2	NVP SUSP	14	0	0	0	14	0		0	0	0	0	
	2	2	NVP SUSP	14	0	0	1	13	0		0	0	0	0	
	3	2	NVP SUSP	13	0	0	0	13	0		0	0	0	0	
	4	2	NVP SUSP	13	7	7	2	18	895.44		535	0	0	0	7
	5	2	NVP SUSP	18	0	0	0	18	0		0	0	0	0	
	6	2	NVP SUSP	18	0	0	2	16	0		0	0	0	0	
	7	2	NVP SUSP	16	0	0	2	14	0		0	0	0	0	
	8	2	NVP SUSP	14	7	7	0	21	895.44		535	0	0	0	14
	9	2	NVP SUSP	21	0	0	2	19	0		0	11	1407.12	0	
	10	2	NVP SUSP	19	0	0	0	19	0		0	0	0	0	
	11	2	NVP SUSP	19	7	7	0	36	895.44		535	0	0	0	20
	12	2	NVP SUSP	36	0	0	1	35	0		0	0	0	0	
2014	1	2	NVP SUSP	35	4	3	2	33	383.76		535	0	0	1	6
	2	2	NVP SUSP	33	0	0	0	33	0		0	0	0	0	
	3	2	NVP SUSP	33	11	10	2	41	1279.2		535	0	0	1	13
	4	2	NVP SUSP	41	0	0	2	39	0		0	0	0	0	
	5	2	NVP SUSP	39	0	0	0	39	0		0	0	0	0	
	6	2	NVP SUSP	39	0	0	1	38	0		0	0	0	0	
	7	2	NVP SUSP	38	7	7	2	43	895.44		535	0	0	0	11
	8	2	NVP SUSP	43	7	7	1	49	895.44		535	0	0	0	10
	9	2	NVP SUSP	49	4	0	5	44	0		600	0	0	4	
	10	2	NVP SUSP	44	7	7	2	49	895.44		600	0	0	0	13
	11	2	NVP SUSP	49	7	7	0	56	895.44		600	0	0	0	14
	12	2	NVP SUSP	56	1441	11	0	67	1407.12		600	0	0	1430	
2015	1	2	NVP SUSP	67	7	6	0	73	767.52		600	0	0	1	4
	2	2	NVP SUSP	73	7	7	0	80	895.44		600	0	0	0	4
	3	2	NVP SUSP	80	1	0	1	79	0		600	0	0	1	
	4	2	NVP SUSP	79	0	0	1	78	0		0	0	0	0	
	5	2	NVP SUSP	78	1441	5	0	83	639.2		600	0	0	1436	5
	6	2	NVP SUSP	83	0	0	1	82	0		0	43	6,140.16	1438	
	7	2	NVP SUSP	39	1441	3	0	42	383.76		600	0	0	1441	6
	8	2	NVP SUSP	42	1441	0	2	40	0		600	0	0	0	
	9	2	NVP SUSP	40	0	0	0	40	0		0	0	0	0	
	10	2	NVP SUSP	40	0	0	1	39	0		0	0	0	0	
	11	2	NVP SUSP	39	0	0	1	38	0		0	0	0	0	
	12	2	NVP SUSP	38	1441	0	0	38	0		600	0	0	1441	
2016	1	2	NVP SUSP	38	0	0	1	37	0		0	0	0	0	
	2	2	NVP SUSP	37	0	0	0	37	0		0	0	0	0	
	3	2	NVP SUSP	37	1441	0	2	35	0		600	0	0	1441	
	4	2	NVP SUSP	35	0	0	2	33	0		0	0	0	0	
	5	2	NVP SUSP	33	0	0	1	32	0		0	0	0	0	
	6	2	NVP SUSP	32	0	0	3	29	0		0	0	0	0	
	7	2	NVP SUSP	29	0	0	2	27	0		0	0	0	0	
	8	2	NVP SUSP	27	0	0	2	25	0		0	0	0	0	
	9	2	NVP SUSP	25	0	0	4	21	0		0	0	0	0	
	10	2	NVP SUSP	21	0	0		21	0		0	0	0	0	
	11	2	NVP SUSP	21	0	0	2	19	0		0	0	0	0	
	12	2	NVP SUSP												

Appendix 8: Dataset of mRDT from health facilities.

Facilit	Year/mont	Item Desc	Initial stock	order	receive	Consumptio	Final closing s	Unit price	Storage cost	Transport cost	Expirec	Cost of	duratio	differe
1	**2012**	M	0	0	0	0	0							
1	2	M	0	75	0	0	0						7	75
1	3	M	0	75	75	13	62	1009.92					7	0
1	4	M	62	0	0	0	62							
1	5	M	62	0	0	13	49							
1	6	M	149	100	100	0	149	1346.56					2	0
1	7	M	149	0	0	25	124							
1	8	M	724	600	600	13	711	8079.36			250		2	0
1	9	M	461	0	0	0	461							
1	10	M	461	0	0	30	431							
1	11	M	631	200	200	25	606	2693.12					4	0
1	12	M	606	0	0	30	576							
1	**2013**	M	576	0	0	30	546							
1	2	M	546	0	0	50	496							
1	3	M	496	0	0	30	466							
1	4	M	466	0	0	0	466							
1	5	M	466	0	0	13	453							
1	6	M	553	100	100	0	553	1346.56					8	0
1	7	M	553	0	0	0	553							
1	8	M	653	100	100	0	653	1346.56					11	0
1	9	M	653	0	0	0	653							
1	10	M	653	0	0	30	623							
1	11	M	623	25	0	0	623				400		2	25
1	12	M	223	0	0	25	198							
1	**2014**	M	198	0	0	13	185							
1	2	M	185	0	0	25	160							
1	3	M	160	0	0	30	130							
1	4	M	230	25	100	15	215	1346.56					13	-75
1	5	M	315	100	0	0	315						6	100
1	6	M	315	0	0	0	315							
1	7	M	315	50	0	0	315						1	50
1	8	M	315	0	0	0	315							
1	9	M	390	75	75	0	390	1009.92					4	0
1	10	M	465	75	75	50	415	1009.92					8	0
1	11	M	415	0	0	0	415							
1	12	M	415	75	0	70	345						1	75
1	**2015**	M	345	0	0	38	307							
1	2	M	307	0	0	25	285							
1	3	M	285	0	0	25	260							
1	4	M	260	0	0	25	235							
1	5	M	235	0	0	25	215							
1	6	M	340	125	125	10	330	1683.2					9	0
1	7	M	330	0	0	30	300							
1	8	M	300	0	0	75	225							
1	9	M	225	1875	0	28	187						13	1875
1	10	M	187	0	0	50	137							
1	11	M	137	0	0	35	102							
1	12	M	102	0	0	5	97							
1	2016	M	97	0	0	25	72							
1	2	M	172	2500	100	50	122	1346.56					9	2400
1	3	M	197	75	75	75	122	1009.92					4	0
1	4	M	272	150	150	35	237	2019.84					1	0
1	5	M	237	0	0	13	224							
1	6	M	224	0	0	13	111							
1	7	M	111	0	0	35	76							
1	8	M	326	1275	250	150	476	3366.4					9	1025
1	9	M	476	0	0	80	396							
1	10	M	396	0	0	30	366				200			
1	11	M	196	0	0	10	186							
1	12	M	186	0	0	50	136							

Appendix 9: Overall dataset of mRDT for the all health facilities in Oshana region.

Year-Month	Item Description	Initial stock	Qty ordered by RMS from CMS	Qty received by RMS from CMS	Qty ordered by HFs from RMS	Qty issued to HFs	Closing stock	Differenc e(order… from	Differenc e(order… from	Duration in days(fr	Duration in days(fr	Transport cost	storage cost	expired quanti	cost expired… cost
2012-01	MALARIA TEST KIT	0	7200	7200	10125	1200	6000	0	357	17	12				
2012-02	MALARIA TEST KIT	6000	15000	9000	2500	950	14050	6000	1550	27	2				
2012-03	MALARIA TEST KIT	14050	0	0	475	475	13575	0	0		2				
2012-04	MALARIA TEST KIT	13575	5700	5700	2800	1525	17750	-1500	1275	27	13				
2012-05	MALARIA TEST KIT	17750	16200	16200	900	600	33350	0	300	15	20				
2012-06	MALARIA TEST KIT	33350	0	0	350	350	33000	0	0		2			20000	269,312
2012-07	MALARIA TEST KIT	13350	3600	3600	300	300	16650	0	0	20	16				
2012-08	MALARIA TEST KIT	16650	0	0	975	2425	14225	0	-1450		2				
2012-09	MALARIA TEST KIT	14225	9000	9000	5150	3900	19325	0	1250	3	1				
2012-10	MALARIA TEST KIT	19325	7200	7200	1600	1600	24925	0	0	21	1				
2012-11	MALARIA TEST KIT	24925	0	0	750	775	24150	0	-25		13				
2012-12	MALARIA TEST KIT	24150	10800	10800	50	50	34900	0	0	27	0				
2012-01	MALARIA TEST KIT	34900	0	0	850	850	34050	0	0		2				
2013-02	MALARIA TEST KIT	34050	12600	14700	2825	8900	39850	-2100	-6075	49	1				
2013-03	MALARIA TEST KIT	39850	0	0	600	2700	37150	0	-2100		0				
2013-04	MALARIA TEST KIT	37150	16800	18900	4475	1625	54425	-84	114	33	3				
2013-05	MALARIA TEST KIT	54425	0	0	4225	2650	51775	0	1575		4				
2013-06	MALARIA TEST KIT	51775	6300	6300	2525	2025	42950	0	500	16	3			15000	201,984
2013-07	MALARIA TEST KIT	27950	8400	8400	6925	4500	31850	0	2425	29	1				
2013-08	MALARIA TEST KIT	31850	0	0	1600	1425	30425	0	175		2				
2013-09	MALARIA TEST KIT	30425	31500	0	100	125	30300	31500	-25	20	16				
2013-10	MALARIA TEST KIT	30300	16800	0	4450	4900	25400	16800	-450	22	1				
2013-11	MALARIA TEST KIT	25400	0	0	825	475	24925	0	350		6				
2013-12	MALARIA TEST KIT	24925	0	0	725	725	24200	0	0		2				
2014-01	MALARIA TEST KIT	24200	0	0	2000	1600	22600	0	400		12				
2014-02	MALARIA TEST KIT	22600	42000	0	1475	275	22325	42000	1200	30	2				
2014-03	MALARIA TEST KIT	22325	0	0	75	75	22250	0	0		14				
2014-04	MALARIA TEST KIT	22250	0	0	4175	4300	17950	0	-125		4				
2014-05	MALARIA TEST KIT	17950	0	0	400	400	17550	0	0		3				
2014-06	MALARIA TEST KIT	17550	12600	12600	8125	4625	25525	0	3500	14	1				
2014-07	MALARIA TEST KIT	25525	31500	31500	2300	2725	54300	0	-425	35	2				
2014-08	MALARIA TEST KIT	54300	21000	8400	4525	3525	59175	12600	1000	28	2				
2014-09	MALARIA TEST KIT	59175	21000	21000	7675	7775	72400	0	-100	9	1				
2014-10	MALARIA TEST KIT	72400	21000	21000	1975	1975	91425	0	0	27	2				
2014-11	MALARIA TEST KIT	91425	8400	8400	150	125	99700	0	25	32	15				
2014-12	MALARIA TEST KIT	99700	12600	12600	5450	3700	108600	0	70	20	2				
2014-01	MALARIA TEST KIT	108600	0	0	1275	1725	106875		-450		2				
2015-02	MALARIA TEST KIT	106875	0	0	675	600	106275	0	75	20	3				
2015-03	MALARIA TEST KIT	106275	0	0	2100	2100	104175		0		1				
2015-04	MALARIA TEST KIT	104175	0	0	3875	3375	100800	0	500	30	11				
2015-05	MALARIA TEST KIT	100800	0	0	4700	1700	96100	0	120		1				
2015-06	MALARIA TEST KIT	96100	0	0	1050	1050	95050	0	0	15	1				
2015-07	MALARIA TEST KIT	95050	0	0	5200	2800	92250	0	96		4				
2015-08	MALARIA TEST KIT	92250	16800	16800	6925	1525	92405	0	216	21	11				
2015-09	MALARIA TEST KIT	92405	12600	12600	575	575	104430	0	0	28	2				
2015-10	MALARIA TEST KIT	104430	12600	10800	2350	925	114305	1800	1425	23	12				
2015-11	MALARIA TEST KIT	114305	31500	31500	4250	2450	143355	0	1800	25	2				
2015-12	MALARIA TEST KIT	143355	0	0	2100	2100	141255	0	0		1				
2016-01	MALARIA TEST KIT	141255	8100	8100	12450	6775	142580	0	5675	16	1				
2016-02	MALARIA TEST KIT	142580	75000	16200	2000	500	158280	2352	60	15	1				
2016-03	MALARIA TEST KIT	158280	0	0	4875	2000	156280	0	2875		4				
2016-04	MALARIA TEST KIT	156280	21000	21600	1100	725	177155	-600	375	4	1				
2016-05	MALARIA TEST KIT	177155	43200	21600	5425	125	198030	21600	5300	21	1				
2016-06	MALARIA TEST KIT	198030	63000	18000	5225	2750	213280	1800	99	22	2			13500	181785.6
2016-07	MALARIA TEST KIT	199780	60000	48000	32150	8725	239055	12000	23425	24	2				
2016-08	MALARIA TEST KIT	239055	0	0	7450	7600	231455	0	-150	43	5				
2016-09	MALARIA TEST KIT	231455	0	0	3725	3050	228405	0	675		6				
2016-10	MALARIA TEST KIT	228405	0	0	1925	800	227605	0	45	20	2				
2016-11	MALARIA TEST KIT	227605	0	0	825	825	228430	0	0	25	0				
2616-12		228430	0	0	0	0	228430	0	0						

Appendix 10. Interview guide

1. **Demographic Data.**

Occupation: ----------

Level of education: ----------

Place of work……

Position held……

2. Experience in pharmaceutical supply chain
   - Can you explain how long you have been working in this department?.....
   - What is your core function of this job you are doing?
   - Are you aware of factors that might contributing to the weakness of supply chain of ARV(NVP syrup & mRDT……..
   - How do you intergrate consumption and orders……..
   - Can you explain it in details…….
   - How do you experience the people in the community when these medicines are out of stock?.....
3. How do you view the link between different stakeholders in pharmaceutical supply chain----------
   ----

   ----
4. How do you cope with shortage of these medicines……
5. In your own view how do you want the supply chain system in the region to be-------
   ----
   ----
6. Do you have anything to say about health care providers in supply chain?----------
   ----

   ----
7. Any other comment or something that you want to say?----------
   ----

Appendix 11. Surplus results of NVP syrup and mRDT

Below, is a summary of values of figure 1 which show that, the mean consumption (average monthly consumption) of NVP syrup was 196, 240-ml bottles with a standard deviation of 219.30. A skewed curve reveals that distribution deviates from symmetry around the mean by 1.72; kurtosis indicates distribution is more peaked than normal by 2.52, revealing a standard error of 0.61.

	Mean		Std. Dev	Variance	Skewness		Kurtosis	
	Statistic	Std. Error	Statistics	Statistic	Statistic	Std. Error	Stat	Std. Error
C_p	196.35	28.31	219.30	48092.74	1.72	0.31	2.52	0.61

Cp is the consumption of NVP syrup at Oshakati Multiregional Medical Depot (OMRMD)

The table below shows the expected values and the critical values of figure.1 for chi square. From the above table it follows that $\chi 2 = 53.87(4) = 0.16$. $p > 0.05$, indicating that the test failed to reject the null hypothesis. That means that, statistically there is enough evidence that the distribution of consumption of NVP syrup at OMRMD follows gamma distribution.

Table 1 for Observed and expected frequency of NVP syrup consumption at OMRMD (N=60)

Frequency			
	Observed frequency	**Expected frequency**	**Residual**
6.0	6	21.0	-15.0
8.0	8	16.2	-8.2
9.0	9	9.0	.0
16.0	16	6.0	10.0
21.0	21	7.8	13.2
Total	60		

Test Statistics	
	Frequency
Chi-Square	53.87[a]
df	4
Asymp. Sig.	0.16
a. 0 cells (0.0%) have expected frequencies less than 5. The minimum expected cell frequency is 6.0.	

From table 1, it shows that $\chi 2 = 53.87(4)= 0.16$. $p > 0.05$. Therefore, the test failed to reject null hypothesis.

Table 2 for Observed and Expected frequency of delivery lead time of NVP syrup at OMRMD (N=60)

Frequency			
	Observed frequency	**Expected frequency**	**Residual**
6.0	30	15	15
8.0	10	15	-5
9.0	9	15	-6
16.0	11	15	-4
Total	**60**		

Test Statistics	
	Frequency
Chi-Square	20.13[a]
Df	3
Asymp. Sig.	0.00
a. 0 cells (0.0%) have expected frequencies less than 5. The minimum expected cell frequency is 9.0.	

From table 2 results show that $\chi 2 = 20.13(3) = 0.00$. $p < 0.05$. Therefore, the test rejected null hypothesis. Therefore there is statistically significant, enough evidence that the distribution of delivery time of NVP syrup at OMRMD do not follow gamma distribution.

Since the null hypothesis is rejected under chi square goodness of fit test, Korlomogrov-Smirnov (K-S) goodness of fit test was used to find the probability distribution of delivery time of NVP syrup at OMRMD. K-S is used because of a large sample size in this study. This time the null hypothesis formulated that test ,distribution of delivery time of NVP syrup at OMRMD follow the exponential probability distribution or negative exponential distribution and alternative hypothesis is that distribution of delivery lead time do not follow exponential probability distribution.

Kolmogorov- Smirnov goodness of fit test

One-Sample Kolmogorov-Smirnov Test		
		Frequency
N		7
Exponential parameter.[a,b]	Mean	8.57
Most Extreme Differences	Absolute	0.17
	Positive	0.17
	Negative	-0.11
Kolmogorov-Smirnov Z		0.45
Asymp. Sig. (2-tailed)		0.99
a. Test Distribution is Exponential.		
b. Calculated from data.		

From the K-S goodness of fit test the $p > 0.05$. Hence the test accept the null hypothesis that delivery time follow the exponential distribution.

Below, a summary of frequency-distribution table indicates a mean delivery time at OMRMD (μLT_{OMRMD}) of 12 days. Distribution is skewed to the right by 1.85 and kurtosis is high at the peak of 4.54.

	Mean		Std. Dev	Variance	Skewness		Kurtosis	
	Statistics	Std. Error	Statistics	Statistics	Statistics	Std. Error	Statistics	Std. Error
Delivery time (days)	12.20	2.12	16.43	269.99	1.85	0.31	4.54	0.61

Below is the summary of descriptive statistics which indicate that mean consumption of NVP syrup is 10 B/240ml, with the standard deviation of 0.66. The distribution is skewed to the right at the value of 0.41 and at the peak at the value of -0.15. Note: C_{pc} represents consumption of nevirapine at the clinic.

	Mean		Std. Dev	Variance	Skewness		Kurtosis	
	Stat	Std. Error	Stat	Stat	Stat	Std. Error	Stat	Std. Error
C_{pc}	9.78	0.66	5.15	26.51	0.41	0.31	-0.15	0.61

Below is the summary of the descrptives statistics which indicates the mean consumption or average monthly consumption of mRDT at OMRMD is 2182 tests or 87 pack of 25. The standard deviation is 2179. The distribution is skewed to the right with the skweness of 1.61 and the peak is at the positive kurtosis of 2.29 which is more than in normal distribution.

	Mean		Std. Dev	Variance	Skewness		Kurtosis	
	Statistics	Starndard Error	Statistics	Statistic	Stat	Std. Error	Stat	Std. Error
C_m	2182.50	281.35	2179.30	4749350	1.61	0.31	2.29	0.61

C_m is consumption of mRDTat OMRMD from 2012-2016.

	N	Mean		Std. Dev	Variance	Skewness		Kurtosis	
	Stat	Stat	Std. Error	Stat	Stat	Stat	Std. Error	Stat	Std. Error
Cmh	60	661.30	65.00	503.52	253532.48	0.37	0.31	-1.01	0.61

	Mean		Std. Dev	Variance	Skewness		Kurtosis	
	Stat	Std. Error	Stat	Stat	Stat	Std. Error	Stat	Std. Error
Frequency of delivery time	19.05	1.91	14.79	218.76	0.74	0.31	-0.31	0.61

	Mean		Std. Dev	Variance	Skewness		Kurtosis	
	Stat	Std. Error	Stat	Stat	Stat	Std. Error	Stat	Std. Error
C_{mc}	198.60	20.31	157.33	24752.85	0.52	0.31	-1.06	0.61

C_{mc} is consumption of malaria test kit at the clinics.

Below is the summary of the descrptives statistics which indicates the mean delivery time of mRDT at clinic is 22 days.

	Mean		Std. Dev	Variance	Skewness		Kurtosis	
	Statistics	Std. Error	Statistics	Statistics	Statistics	Std. Error	Statistics	Std. Error
Duration in days at the clinic	22.97	1.48	9.13	83.27	0.37	0.38	1.41	0.75

	N	Mean		Std. Dev	Variance	Skewness		Kurtosis	
	Stat	Stat	Std. Error	Stat	Statistic	Stat	Std. Error	Stat	Std. Error
$\mathbf{C_{ph}}$	60	42.80	2.55	19.77	390.74	-0.10	0.31	0.71	0.61

Cph is Consumption of NVP syrup at health centres.

The following is the guidelines for implementation of optimal mathematical supply chain model based on the probability distribution models at the various levels of supply chain.

Appendix 12. Predictors of stock out of NVP syrup

Predictors of stock out of NVP syrup at OMRMD

Variables in the Equation						
Predictors	**B**	**S.E.**	**Wald**	**df**	**Adjusted odds ratio, CI 95%**	**P value**
Delivery lead time	.049	.052	.889	1	1.050 (.949-1.161)	.346
Initial stock	.004	.003	1.650	1	1.004(.998-1.009)	.199
Total HIV pregnant mothers	.004	.033	.014	1	1.004(.942-1.070)	.906
HIV prevalence pregnant mother	.013	0.031	1.033	1	1.003(.9101-1.123)	.309
HIV incidence pregnant mother	.011	3.193	2.671	1	1.002(.353-1.037)	.102

Predictors of stock out of NVP syrup at HCs.

Variables in the Equation						
Predictors	**B**	**S.E.**	**Wald**	**df**	**P value**	**Adjusted odds ratio, CI 95%**
Delivery lead time	0.420	0.563	.019	1	.041	1.003(.778-1.009)
HIV incidence pregnant mother	0.045	0.075	.018	1	.894	1.012(.912-1.060)
HIV prevalence pregnant mother	0.358	0.586	.013	1	.909	1.004(.9001-1.113)
Initial stock	0.024	0.412	.020	1	.788	1.002(.253-1.037)

Predictors of stock out of NVP syrup at the clinics.

Variables in the Equation						
Predictors	**B**	**S.E.**	**Wald**	**df**	**Adjusted odds ratio, CI 95%**	**P value**
Delivery lead time	0.320	0.463	.014	1	1.001(.761-1.008)	0.021*
HIV incidence pregnant mother	0.044	0.063	.016	1	1.002(.602-1.060)	.694
HIV prevalence pregnant mother	0.238	0.086	.013	1	1.004(.8002-1.113)	.709
Initial stock	0.021	0.332	.023	1	1.002(.233-1.037)	.728
Consumption clinic	0.011	0.030	.028	1	1.001(.131-1.104)	.317
Total HIV pregnant mothers	0.012	3.113	.641	1	1.001(.129-1.136)	.462

Appendix 13. Predictors of stock out of mRDT

Predictors of stock out of mRDT at OMRMD

Variables in the Equation						
	B	S.E.	Wald	df	Adjusted odd ratio	P value
Delivery lead time	.033	.025	1.841	1	1.034(.985-1.085)	.175
Average Temperature °C	.693	.469	2.183	1	1.999(.7985.012)	.140
Rainfall in mm	.036	.020	3.352	1	1.036(.997-1.077)	.067

Predictors of stock out of mRDT at HC

Variables in the Equation						
	B	S.E.	Wald	df	Adjusted odd ratio	P value
Average Temperature in °C	.737	.469	2.465	1	2.089 (.833-5.239)	.116
Rainfall in mm	.038	.020	3.682	1	1.039(.999-1.081)	.055

Predictors of stock out of mRDT at the clinics

Variables in the Equation						
	B	S.E.	Wald	df	Adjusted odds ratio	P value
Average Temperature in C	1.008	.617	2.665	1	2.740 (.817-9.189)	.103
Rainfall in mm	.049	.025	3.809	1	1.050 (1.000-1.103)	.05
Delivery lead time	.095	.067	2.034	1	1.100 (.965-1.253)	.154