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Supply Chain Management Challenges of COVID-19 Testing: The case of Health Facilities in Addis Ababa

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ADDIS ABABA UNIVERSITY SCHOOL OF COMMERCE

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Approved by Board of Examiners and Advisor

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Chairman of Graduate Committee	Signature	Date

DECLARATION

I, Kifle Teferi, declare that the paper which is being presented in this thesis entitled Supply Chain Management Challenges of COVID-19 Testing Reagents: the case of Health Facilities in Addis Ababa is original work of my own, has not been presented in any of other university and that all references used for the thesis have been duly acknowledged.

Name: Kifle Teferi

Signature: ____________________________ Date: ______________________________

This is to certify that the above declaration made by the candidate is correct to the best of my knowledge.

Confirmed by: Tariku Jebena (PHD)

Signature: _____________________________ Date: ______________________________

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Abstract

The purpose of study is to assess supply chain management challenges of COVID-19 PCR testing reagents in health facilities in Addis Ababa city. Furthermore, the study has attempted to spotlight on the effects of these challenges on the testing services of these health facilities. A mixed research approach was used in the study. All 26 health facilities actively participating in the testing service were included. Data were generated using questionnaire distributed to professionals participating (52) in the supply chain management of the reagents at these health facilities. The respondents were selected based on purposive sampling that included medical laboratory heads and logistics officers. The collected data has been analyzed using both descriptive and inferential statistics aided by SPSS version 23. Consequently, the findings indicated that the main challenges are inadequacy of refrigerated vehicles, inefficient storage space, disproportioning of reagents, stock out of reagents, inadequate training of professions, non-automation of the logistics management information system, emergency order of reagents, weak partnership between public and private facilities, logistics management information system being not integrated with laboratory management information system, stock out of reagents, shortage of trained professionals, interruption in testing services, elongated turnaround time and backlog of untested samples.

Findings from the regression analysis show that the challenges in distribution and transport, storage and handling, logistics management information system, inventory management, human resource management and public–private partnership collectively explain that 76.9 % of the change in average duration of service interruption.. Besides, it is revealed that the challenges in distribution and transport, inventory management and public–private partnership are statistically significant in explaining average duration of service interruption.

Finally, the study recommends that Public and private health facilities to give attention to partnership, health facilities to prepare trainings, platform be created and shared among all health facilities, focus given to supply chain management in the health sector and the ministry of health to participate in creating conducive environment for public-private partnership.

Key words: supply chain management challenges, testing service availability

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Abbreviations

CDC – Center for disease control

COVID -19 – Corona virus disease 2019

CSCMP - Council of Supply Chain Management Professionals

CSCS – COVID-19 supply chain system

DNA – Deoxyribonucleic acid

dNTPS - Deoxynucleoside triphosphates

EPHI – Ethiopian public health institute

JSI – John Snow institute

PCR – Polymerase chain reaction

PPP – Public private partnership

SOP – Standard operating procedure

LIMS – Logistics management information system

LMICs – Low and middle income countries

MOH – Ministry of health

MSH – Management sciences for health

NICD – National Institute for Communicable Diseases

POC – Point of care

QC – Quality control

RNA – Ribonucleic acid

SARS-COV-2 – Severe acute respiratory syndrome corona virus 2

SDPs – Service delivery points

USAID – United states aid

WHO – World health organization

Chapter one

Introduction

As an introductory part this section contains issues such as Background of the study, statement of the problem, research questions, research objective, significance of the study, scope of the study, hypothesis testing and organization of the study.

1.1 Background of the study

According to the Council of Supply Chain Management Professionals (CSCMP), Supply chain management encompasses the planning and management of all activities involved in sourcing and procurement and all logistics management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third party service providers, and customers. In essence, supply chain management integrates supply and demand management within and across companies. Logistics activities are the operational component of supply chain management, including functions such as quantification, procurement, inventory management, warehousing, transportation and fleet management, and data collection and reporting. Supply chain management includes the logistics activities plus the coordination and collaboration of staff, levels, and functions, with the ultimate goal of aligning supply and demand.

A strong health system cannot function without a well-designed, well-operated, and well maintained supply chain management system; one that can ensure an adequate supply of essential health commodities to the clients who need them. A public health supply chain is a network of interconnected organizations or actors that ensures the availability of health commodities to the people who need them. Supply chains also help determine the success or failure of any public health program. Both in business and in the public sector, decision-makers increasingly direct their attention to improving supply chains, because these improvements bring important, quantifiable benefits. Well-functioning supply chains benefit public health programs in important ways by increasing program impact, enhancing quality of care and improving cost effectiveness and efficiency (JSI, 2017).

The goal of a health logistics system is much larger than simply making sure a product gets where it needs to go. Ultimately, the goal of every public health logistics system is to help ensure that every customer has commodity security. Commodity security exists when every person is able to obtain and use quality essential health supplies whenever he or she needs them. A properly functioning supply chain is a critical part of ensuring commodity security financing, policies, and commitments are also necessary. Effective supply chains not only help ensure commodity security, they also help determine the success or failure of any public health program. Both in business and in the public sector, decision makers increasingly direct their attention to improving supply chains, because logistics improvements bring important, quantifiable benefits. Well-functioning supply chains benefit public health programs in important ways by increasing program impact, enhancing quality of care and improving cost effectiveness and efficiency (USAID | Task Order 1, 2011).

Laboratory services play a significant role in a country's public health system and in the delivery of quality health services. Laboratory capacity depends on the availability of the required commodities to perform laboratory tests, with most tests requiring multiple commodities to be available simultaneously. Well-functioning supply chains will enhance availability of the commodities required to provide the necessary laboratory services. The ultimate goal of any supply chain is to get products to customers (USAID | DELIVER PROJECT, 2008).

Laboratory logistics system is important for Public health programs which depend on laboratory testing for: screening, diagnosis, and patient management and disease surveillance. Without supplies, labs cannot perform tests; compromising provision of vital services additionally many tests require simultaneous availability of multiple commodities. (USAID/DELIVER PROJECT, 2009). Laboratory logistics systems manage a vast array of testing commodities, with varying characteristics, for a diverse number and type of service delivery points (SDPs). These commodities are used for laboratory testing services which are required for a number of important public health purposes. Laboratory products required for each of these testing services may also vary greatly. Some products must be delivered to facilities every month because of their short shelf lives. Other products may have different physical requirements, such as temperature sensitivity and packaging size, often requiring special storage and distribution handling (Mwencha *et al.*, 2010)

Several characteristics peculiar to laboratory commodities affect the design and management of the logistics system. These are the need for large numbers of commodities; laboratory commodities come in a variety of preparations, including dry powders, liquids, and kits; dry laboratory chemicals and consumable liquids are often packaged in bulk; some laboratory commodities have extremely short shelf lives; for example, some control reagents have a shelf life of 3 months or less and some laboratory commodities have special storage requirements, such as cold-chain storage (USAID | DELIVER PROJECT, 2008).

This study is conducted to assess the supply chain challenges of COVID 19 PCR testing reagents in both governmental and private health facilities of Addis Ababa city and to identify the possible challenges that exist in the supply chain of these laboratory reagents as well as testing service availability which are critical components in COVID 19 testing and so does in combating the pandemic. As a result this study will help decision makers and other stakeholders in the health sector to have an insight about the supply chain challenges of COVID 19 PCR testing reagents in the city.

1.2 Statement of the problem

There is limited research on the supply chain management of point of care diagnostic testing in resource-limited settings. POC diagnostic services are fundamental in the timely control and management of COVID-19. The supply chain of POC diagnostic testing should be optimized to ensure access to all patients. The adoption of digital technology can play a crucial role in mitigating the supply chain management challenges arising from the COVID-19 pandemic. There is currently no research focusing on the supply chain management of POC tests in the control and management of COVID-19. Therefore, there is an urgent need to conduct primary studies that will investigate the supply chain management for SARS-CoV-2 POC testing services in order to reveal the research gaps and provide evidence-based solutions for policymakers and implementers of this service (Maluleke *et al.*, 2021).

Managing supply chains in support of laboratory services is a formidable challenge, especially in developing countries. Laboratory services play a significant role in a country's health system and in the delivery of quality health services. Laboratory capacity depends on the availability of the required commodities to perform these tests, with most tests requiring multiple commodities to be available simultaneously. Well-functioning supply chains will enhance availability of the commodities required to provide the necessary laboratory services (Mwencha *et al.*, 2010).

Laboratory products required for testing services vary greatly. Some products must be delivered to facilities every month because of their short shelf lives. Other products may have different physical requirements, such as temperature sensitivity and packaging size, often requiring special storage and distribution handling (Mwencha *et al.*, 2010). Several characteristics peculiar to laboratory commodities affect the design and management of the logistics system. These are the need for large numbers of commodities; laboratory commodities come in a variety of preparations, including dry powders, liquids, and kits; dry laboratory chemicals and consumable liquids are often packaged in bulk; some laboratory commodities have extremely short shelf lives; for example, some control reagents have a shelf life of 3 months or less and some laboratory commodities have special storage requirements, such as cold-chain storage (USAID | DELIVER PROJECT, 2008).

Challenges in the supply chain management of laboratory commodities includes challenges in inventory management such as frequent stock outs of reagents ,weak or no standard ordering process and procedures , no established pipeline ,multiple vertical pipelines , rationing of commodities, associated products not ordered concurrently, existing pipeline too long; challenges of storage and distribution such as cold chain is required for certain reagents, flammables and corrosives require special handling considerations, light-sensitive chemicals require special consideration and short shelf life of some commodities may require that products be managed and distributed separately, and almost immediately upon arrival in-country, to avoid expiration; challenges quality assurance and quality control such as lack of standardization of laboratory tests, techniques, and procedures, lack of internal QC materials, lack of procedures and knowledge for visual inspection of laboratory commodities and for disposal of expired or damaged commodities, failure to participate in external quality assurance programs and lack of continuous supply of high-quality laboratory commodities; challenges in management and staffing such as staff members not trained in logistics management or evaluating considerations for new products (storage, supply chain, resupply procedures, or issues), limited number of personnel, lack of supervision and unclear or weak laboratory administrative structures (USAID/DELIVER PROJECT, 2009).

During the process of laboratory testing capacity expansion for COVID-19 in Ethiopia some key challenges were faced. A weak supply chain management for laboratory reagents and supplies was a major concern. As a result, there were interruptions in COVID-19 testing, back logs of untested samples and prolonged waiting time for sample collection from suspect cases. These delays could have increased the risk of spread of COVID-19 infection as suspect cases were not timely tested (Kebede *et al.*, 2021).

1.3 Research questions

The thesis has sought answers to the following questions:

- What are the main challenges of distribution and transportation of COVID-19 PCR testing reagents in both private and government facilities of Addis Ababa city?
- What are the challenges related with the storage and handling of the reagents in the health facilities of the city?
- What are challenges related with inventory management of the reagents in the health facilities?
- What are the main challenges in human resource management of the professionals responsible to the logistics of the reagents?
- What are the main challenges related to the logistics information management system of the reagents?
- What are the main challenges in public-private relationship in the supply chain system?
- What are the problems of COVID-19 PCR testing service delivery related to supply chain challenges?

1.4 Objective of the Study

1.4.1 General objective

The general objective of the study is to assess supply chain challenges of COVID-19 PCR testing reagents along with their effects in health facilities in Addis Ababa city.

1.4.2 Specific objectives

The specific objectives of the thesis are:

1. To describe the challenges of distribution and transportation of the reagents in both private and government facilities.
2. To describe challenges related with the storage and handling of the reagents in the health facilities of the city.
3. To describe challenges related with inventory management of the reagents in the health facilities of the city.

4. To describe challenges of human resource and required knowledge of professionals responsible to the logistics of the reagents.
5. To describe the logistics information management system being utilized for managing the reagents supply chain.
6. To describe the main challenges in public-private relationship in the supply chain system of the reagents.
7. To test the effect of supply chain challenges on the COVID-19 PCR testing service delivery in the testing facilities.

1.5. Hypotheses of the Study

The thesis has tested the following Hypotheses which are formulated based on the specific objective (No 7) above.

H1: Challenges in distribution and transportation have a significant effect on the COVID 19 PCR testing service interruption of Health Facilities in Addis Ababa.

H2: Challenges related with the storage and handling of the reagents has a significant effect on the COVID 19 PCR testing service interruption of Health Facilities in Addis Ababa.

H3: Challenges related with inventory management of the reagents has a significant effect on the COVID 19 PCR testing service interruption of Health Facilities in Addis Ababa.

H4: Challenges of human resource management of professionals responsible to the logistics of the reagents has a significant effect on the COVID 19 PCR testing service interruption of Health Facilities in Addis Ababa

H5: Challenges in the logistics information management system being utilized for managing the reagents supply chain has a significant effect on the COVID 19 PCR testing service interruption of Health Facilities in Addis Ababa.

H6: Challenges in public-private partnership in the supply chain system has a significant effect on the COVID 19 PCR testing service interruption of Health Facilities in Addis Ababa.

1.6 Significance of the study

This study will provide basic information about the supply chain challenges to the parties participating in the supply chain management of COVID-19 PCR testing reagents in both private and governmental health facilities in Addis Ababa city as well as other parts of the country. Addis Ababa city health bureau can use this study as an input to know what challenges of supply chain management are occurring and at which stage of the supply chain management they are occurring helping the organization to act accordingly to alleviate the challenges and to establish a better supply chain system which has a great impact in combating the COVID-19 pandemic.

1.7 Scope of the study

This study is conducted in Addis Ababa city in private health facilities such as laboratory diagnostic centers, hospitals and medical centers as well as in governmental health facilities such as public health institutes, hospitals and regional laboratories that are currently giving the service of COVID-19 PCR testing. The study has covered issues related with storage condition, handling, inventory management, distribution, transportation, human resource management, information management system of COVID-19 PCR testing reagents and testing service availability in the health facilities during the pandemic.

1.8 Organization of the study

The research work is organized in such a way in five chapters. The first chapter is the introduction part that contains background of the study, statement of the problem, objectives, research questions, scope of the study, significance of the study, organization of the study, and limitation of the study. The second chapter covers the literature review of the study (theoretical literature review and empirical literature review) and conceptual framework which relies on the review of related literatures. The third chapter presents the research methodology containing description of the study area, the study design and approach, the population and sampling method used, data collection activities, the data analysis procedures and ethical consideration. The fourth chapter deals with the data analysis and discussions in which the data collected is analyzed and discusses the findings of the research. The final chapter presents the summary of the research and the research findings, recommendation and conclusion of the study.

Chapter 2

Literature Review

2.1 Theoretical review

2.1.1 Supply chain management

According to the Council of Supply Chain Management Professionals (CSCMP); Supply chain management encompasses the planning and management of all activities involved in sourcing and procurement and all logistics management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third party service providers, and customers. In essence, supply chain management integrates supply and demand management within and across companies. Logistics activities are the operational component of supply chain management, including functions such as quantification, procurement, inventory management, warehousing, transportation and fleet management, and data collection and reporting. Supply chain management includes the logistics activities plus the coordination and collaboration of staff, levels, and functions, with the ultimate goal of aligning supply and demand (JSI, 2017).

Supply chains are composed of numerous logistical processes to ensure efficient flow of commodities. Good management of supply chain processes ensures six basic customer rights namely: the right commodities, in the right quantities, in the right condition, delivered, to the right place, at the right time and for the right cost (USAID | Task Order 1, 2011)

2.1.2 Supply chain of health commodities

A strong health system cannot function without a well-designed, well-operated, and well-maintained supply chain management system; one that can ensure an adequate supply of essential health commodities to the clients who need them. A public health supply chain is a network of interconnected organizations or actors that ensures the availability of health commodities to the people who need them. Supply chains also help determine the success or failure of any public health program. Both in business and in the public sector, decision-makers increasingly direct their attention to improving supply chains, because these improvements bring important, quantifiable benefits. Well-functioning supply chains benefit public health programs in important ways by increasing program impact, enhancing quality of care and improving cost effectiveness and efficiency (JSI, 2017)

The logistics cycle provides a guiding framework of the functions needed to manage all health commodities, including medical laboratory commodities. Specific issues and considerations for managing each of those functions for laboratory commodities follow, along with recommendations for logistics system design and implementation for laboratory commodities (USAID/DELIVER PROJECT, 2009).

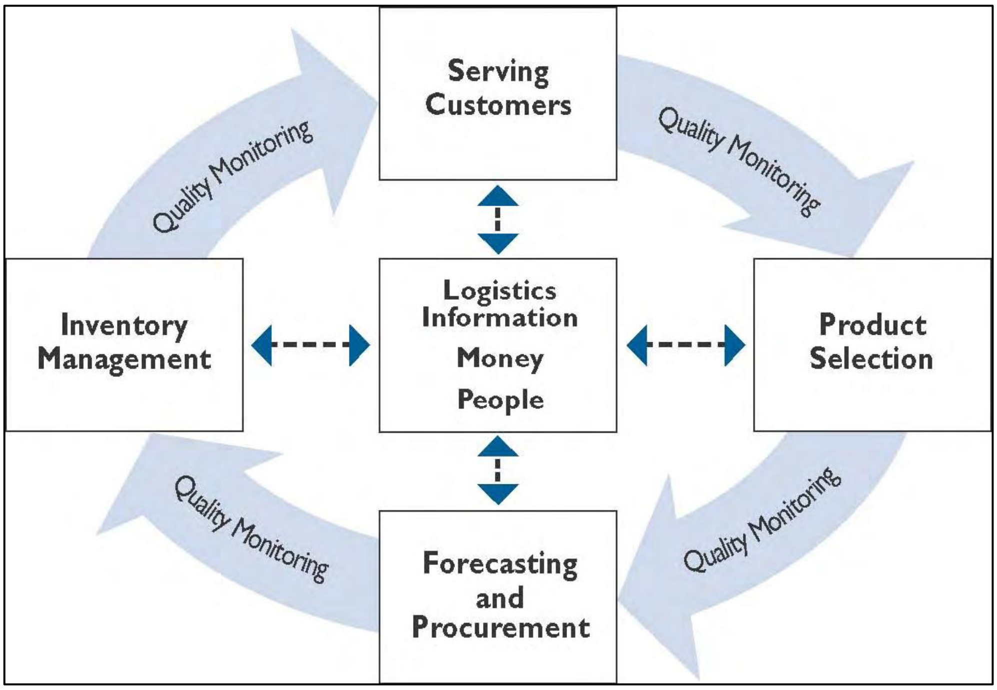


Fig 2.1 The logistics cycle (USAID /DELIVER PROJECT, 2009)

2.1.3 Supply chain of laboratory commodities

Public health and clinical laboratory services play a vital role in a country's health system delivery. For health laboratory services to be successful, it is essential that labs operate within a system that provides the necessary support for the entire network of labs, including support for supply chain activities, from central to intermediate to peripheral labs (USAID/DELIVER PROJECT, 2009). Benefits of supply chain & logistics to successful laboratory services includes strengthening the supply chain of laboratory system for efficient health care services delivery, integrated approach to supporting all laboratories through supply chain assistance, harmonize laboratories commodities supplies for quality monitoring, reduce stock-out, minimize wastages due to expiries and consolidate procurement for cost savings (Kumurya, 2015).

Laboratory logistics systems manage a vast array of testing commodities, with varying characteristics, for a diverse number and type of service delivery points (SDPs). These commodities are used for laboratory testing services which are required for a number of important public health purposes. Laboratory products required for each of these testing services may also vary greatly. Some products must be delivered to facilities every month because of their short shelf lives. Other products may have different physical requirements, such as temperature sensitivity and packaging size, often requiring special storage and distribution handling (Mwencha *et al.*, 2010).

The characteristics of laboratory commodities affect the design and management of the logistics system. For example, reagents can come in a variety of preparations (solid, powder, liquid). The physical presentation of a commodity has implications for how data are collected and reported, storage and distribution, and quantification (USAID/DELIVER PROJECT, 2009).

The unique characteristics of laboratory commodities impact the way in which the supply chain should be designed and managed to ensure the availability of these commodities. These characteristics include : Large numbers of commodities are needed: Laboratory commodities come in a variety of preparations, including dry powders, liquids, and kits; Dry laboratory chemicals and consumable liquids are often packaged in bulk; Some laboratory commodities have extremely short shelf lives; for example, some control reagents have a shelf life of three months or less and Classifying laboratory commodities is critical to designing, implementing, and managing supply chains for those commodities (USAID/DELIVER PROJECT, 2009).

Managing supply chains in support of laboratory services is a formidable challenge, especially in developing countries. Laboratory services play a significant role in a country's health system and in the delivery of quality health services. Laboratory capacity depends on the availability of the required commodities to perform these tests, with most tests requiring multiple commodities to be available simultaneously. Well-functioning supply chains will enhance availability of the commodities required to provide the necessary laboratory services (Mwencha *et al.*, 2010).

Challenges in the supply chain management of laboratory commodities includes challenges in inventory management such as frequent stock outs of reagents ,weak or no standard ordering process and procedures , no established pipeline ,multiple vertical pipelines , rationing of commodities, associated products not ordered concurrently (buffer solution, lancets, etc.) , existing pipeline too long; challenges of storage and distribution such as cold chain is required for certain reagents, flammables and corrosives require special handling considerations, light-sensitive chemicals require special consideration and short shelf life of some commodities may require that products be managed and distributed separately, and almost immediately upon arrival in-country, to avoid expiration; challenges quality assurance and quality control such as lack of standardization of laboratory tests, techniques, and procedures, lack of internal QC materials, lack of procedures and knowledge for visual inspection of laboratory commodities and for disposal of expired or damaged commodities, failure to participate in external quality assurance programs and lack of continuous supply of high-quality laboratory commodities; challenges in management and staffing such as staff members not trained in logistics management or evaluating considerations for new products (storage, supply chain, resupply procedures, or issues), limited number of personnel, lack of supervision and unclear or weak laboratory administrative structures (USAID/DELIVER PROJECT, 2009).

2.1.4 PCR testing of COVID-19

Diagnostics and testing are a cornerstone of the management and control of the ongoing coronavirus disease (COVID-19) pandemic. Detection of cases and isolation of infected individuals are critical to interrupt disease transmission. Diagnostics are vital for each stage of addressing the disease: (1) detection of the disease; (2) assessing and reporting the spread of the disease and associated risks; and (3) response to the disease, including infection prevention and control, mitigation, and recovery. The processes, principles, and methodologies used for estimating COVID-19 laboratory diagnostic requirements are similar to that of commodities for other diseases. Countries, particularly LMICs, can use the experiences and expertise garnered by managing other health programs such as HIV and AIDS, malaria, and TB to estimate COVID-19 diagnostics requirements (MSH, 2020).

PCR test is a molecular diagnostic test that detects viral RNA, amplify specific genetic sequences that are unique to the virus, and produce a readable output that can be interpreted by laboratory experts, healthcare providers, or the patient. The amplification step allows the test to identify even low levels of viral infection, such as those found at the beginning of an active infection. These tests were created to be highly specific to the SARS-CoV-2 virus, thereby minimizing false positive results, and to detect low viral loads in respiratory samples. These types of tests require trained research personnel to run samples and interpret results. Although PCR tests can take 2 to 4 hours to complete in a laboratory environment, return of results can take much longer due to processing times and high volumes of patient samples (Kobokovich and West, 2021).

2.1.5 COVID-19 PCR testing reagents

Reagents are chemicals and biological agents that are used in laboratory testing for detecting or measuring an analyte, the substance being measured or determined. The reagents vary widely in cost, stability, cold- or cool-chain requirements, availability, and the hazards associated with each variant (USAID | DELIVER PROJECT, 2008).

PCR clean reagents, enzymes, buffer, dNTPS and primers are required to be stored at -20 ^{0}C.The primers, dNTPS and water should be stored in small aliquots to avoid freezing and thawing effect and also to rule out contamination issues. Separate refrigerators for temporary storage of sample, extracted RNA/nucleic acid and final amplification products should be maintained in the respective laboratory. Usually long term storage is not recommended but if needed separate deep freezers (-80 ^{0}C) can be maintained. The PCR products may also be stored at -20°C or - 70°C. RNA templates should be aliquoted and stored at -70°C(WHO, 2011)

2.1.6 Distribution and storage of COVID-19 reagents

Effective reagent distribution systems rely on sound system design and the right management approach. The COVID-19 context and testing strategy in LMICs will largely influence the test distribution system's design. A well-designed and well-managed distribution system should: Maintain a constant supply of tests, and accompanying reagents, Keep tests, reagents, and associated testing materials in the right conditions throughout the distribution process, Minimize Covid-19 diagnostics losses caused by spoilage, poor storage, and expiry, Maintain accurate inventory records, Optimize storage points/location, Support near-POC testing arrangements, especially for centralized test sites, Utilize both public and third-party private logistics systems to ensure efficiencies and effectiveness in distribution, storage, and transport, Reduce misappropriation of lab resources, theft, and diversions and Provide information for forecasting demands on an ongoing basis (MSH, 2020).

The required distribution and warehousing parameters for LMICs to consider during the COVID-19 pandemic include testing strategy, degree of centralization of tests, number of levels or sites of tests, geographic distribution of test sites, health facility–based or national laboratory–based test sites and the population coverage. Many LMICs will rely on or modify the existing logistics infrastructure and/or design a new system. An approach that changes the existing systems to introduce an informed push system while consolidating storage points, introducing transport loops, and increasing human resource capacity for distribution is recommended. Whichever distribution approach is adopted, it will be served well if a rapid option or cost analysis is done to support decision making to assure the availability of appropriate storage, transport, and above all, the required human resources for effective and improved access to tests by all. Once diagnostics tests arrive and are inventoried, the local storage processes should align with the manufacturer's specifications. The potency of some health products and test kits depends on the temperature of storage. Some tests and reagents may require refrigeration and storage below the ambient temperature, while others can be stored at room temperature. If no specific storage directives are given, normal storage conditions apply: store in dry, well-ventilated premises at temperatures of 15 ^{o}C– 25 ^{o}C or, depending on climatic conditions, up to 30 ^{0}C. It is important to check storage temperatures in each storage zones regularly (MSH, 2020).

2.2 Empirical literature review

2.2.1 Supply chain management challenges of COVID-19 testing

The primary goal of severe acute respiratory syndrome coronavirus type 2 (SARS- CoV-2) testing is to reduce the spread of coronavirus disease 2019 (COVID-19). Due to the highly infectious nature of SARS-CoV-2, there is an urgent need for a fast turnaround of results to institute preventative measures such as the isolation of confirmed cases and contact tracing. Currently, reverse transcription polymerase chain reaction (RT-PCR) tests are the gold standard for diagnosing COVID-19. The laboratory equipment required to perform RT-PCR test is often lacking in resource-limited settings, hindering the fast and accurate detection of SARS-CoV-2 in diagnostic laboratories. It is revealed that stock outs of diagnostic tests were caused by problems in procurement, inventory management, storage, distribution and quality assurance (Maluleke *et al.*, 2021).

The global nature of the COVID-19 pandemic has led to an acute and drastic shortage of some essential supplies, including diagnostics. The coordinated efforts by the global health community improved availability of manual PCR tests for low income countries and middle income countries that are currently estimated to be approaching the capacity of those countries to consume them. However, the availability of automated PCR tests for high-throughput platforms and, even more so, of point of care PCR tests remains critically limited for LICs and MICs Many countries are prevented from scaling-up their COVID-19 testing programmes using manual PCR testing due to facing constraints related to cold chain requirements, central laboratory settings, the need for highly trained specialized laboratory technicians, amongst others (United Nations Children's Fund, 2020).

The main Supply Chain Challenges of COVID-19 testing commodities were Access for COVID-19 diagnostics is very difficult due to temporary export restriction on COVID-19 related products including diagnostics by many countries; supply of incomplete materials mainly donations; lack of forecasting and quantification at country level and quality of products . Additionally Time to deliver COVID-19 testing items to member States of 29 African countries shows that 48% of distributed laboratory testing commodities for COVID-19 delivered in 3 days or less; 30% of the testing commodities delivered between 4- 10 days and the rest 22% of testing commodities delivered above 10 days (Kebede, 2020).

From Ethiopian experience one of the critical challenges we are facing in combating the COVID-19 pandemic is the inadequate well-trained human capital in terms of sample collection and delivery, testing and test result dispatching. Additional challenges include lack of adequate infrastructure, logistics constraints, lack of reference laboratories and lack of data and weak statistical capacity (Mulu *et al.*, 2021)

Swift collection and testing of biological samples from patients meeting the suspected case definition for COVID-19 are critical for proper monitoring and control of disease infection in the community. The WHO has recommended the testing of COVID-19 infection using a reverse transcription polymerase chain reaction (RT-PCR)-based protocol to target different viral genes. However, these testing protocols require RNA extraction kits, costly RT (quantitative) PCR machines and trained technicians to operate them. These resources are limited in countries with poor scientific infrastructure, such as Nepal, where there was only one laboratory equipped to test for coronavirus infection, with an increase to three planned for the end of March 2020. The establishment of fully equipped testing laboratories that fulfill WHO guidelines would require huge investment, expertise and time, which are currently limited by the COVID-19 crisis. Alternative testing protocols that allows COVID-19 testing with limited resources and available manpower in the country, will be highly useful in the fight against the COVID-19 pandemic (Giri and Rana, 2020a).

Laboratory capacities for COVID-19 testing like almost all countries in Africa, Ethiopia did not have the capacity to test for COVID-19 at the onset. Samples were initially transported for testing to the National Institute for Communicable Diseases (NICD) Laboratory in South Africa, a WHO regional reference laboratory. With support from WHO and the Africa Centres for Disease Control and Prevention, EPHI set up the National Influenza and Arboviruses Reference Laboratory as the first COVID-19 testing laboratory in the country by February 2020. Capacity building for laboratory technicians was conducted and donations of COVID-19 detection and extraction kits and reagents were made. The COVID-19 IMS set up by Federal Ministry of Health and led by the Minister of Health Source consisted of 18 pillars with subunits. Based on their expertise, individuals were appointed to lead and coordinate readiness and response activities under each pillar. BMJ Global Health continued to support external quality control testing with samples shipped to NICD. Expansion of COVID-19 laboratory testing sites to the regional states was ramped up early in the response through the pre-existing laboratory network with regional public health laboratories, universities and laboratories under the Ministry of Agriculture (Lanyero *et al.*, 2021)

From Senegal experience there were two major challenges in COVID-19 testing supply chain management. First, sample collection kits and personal protective equipment that are in short supply due to heightened global demand due to which whole supply chain has been affected. Secondly, the personnel and logistics needed for effective COVID-19 testing. There was a continuous recruitment process and training to ensure that we have enough personnel. For supplies, we do regular resource mobilization and work with major institutions to procure reagents, supplies and equipment (Banda, 2022).

The WHO strongly recommends testing of suspects for COVID-19 and the individuals who have been in contact with them in order to control the infection in a community. However, due to the high infectivity of the virus and lack of appropriate resources (e.g., testing laboratories, kits), most of the world is struggling to contain the spread of virus and is facing an increasing number of fatalities. Risk of mortality is much higher in developing countries with poor scientific and health infrastructure and these countries are struggling to test for and track the infection due to a lack of laboratory facilities and trained manpower. Lack of equipped diagnostics with appropriate instruments and testing kits and safety information, as well as social prejudices about the disease are other barriers to the fight against the virus in the developing world. In this manuscript, we outline these problems and discuss strategies that can be adapted for the rapid detection of COVID-19 in developing countries + distribution and storage (Giri and Rana, 2020b).

At country level logistical arrangements to support incident management and operations needs to be reviewed. Expedited procedures may be required in key areas such as surge human resources deployments, procurement of essential supplies and contractor payments. Due to acute supply shortages, the COVID-19 supply chain system (CSCS) has been established to provide countries with essential supplies for their COVID-19 response. This platform also should be used to address supply challenges for maintaining essential services where relevant, to allow equitable allocation between all health care providers when supply shortages arise. The CSCS is led by the Supply Chain Task Force, which is co-chaired by WHO and WFP. The CSCS will facilitate the identification, certification, sourcing, allocation and delivery of essential supplies to where they are needed most. The following (but not limited to) key activities will guide the WHO response in this pillar: Support to establish and sustain a system for monitoring stock of essential medical supplies to ensure timely procurement and delivery; Conduct assessments of the logistics capacity and management systems and supporting countries to develop a logistic safety plan; Support countries to update Health Sector Supply Chain Strategy and Implementation of the Action Plan; Train personnel on cold chain maintenance; Build the capacity of OSL teams at national and subnational levels; design and introducing inventory tracking system to ensure end-to-end tracking of wide-ranging commodities; train logisticians at national and sub-national levels in logistics management using electronic solutions (WHO, 2021).

There is limited research on the supply chain management of COVID-19 diagnostic testing in resource-limited settings. Diagnostic services are fundamental in the timely control and management of COVID-19. The supply chain of diagnostic testing should be optimized to ensure access to all patients. The adoption of digital technology can play a crucial role in mitigating the supply chain management challenges arising from the COVID-19 pandemic. There is currently no research focusing on the supply chain management of POC tests in the control and management of COVID-19. Therefore, there is an urgent need to conduct primary studies that will investigate the supply chain management for SARS-CoV-2 testing services in order to reveal the research gaps and provide evidence-based solutions for policymakers and implementers of this service (Maluleke *et al.*, 2021).

During the process of laboratory testing expansion for COVID-19 in Ethiopia, some key challenges were faced in which a weak supply chain management for laboratory reagents and supplies was a major concern. As a result, there were interruptions in COVID-19 testing, back logs of untested samples and prolonged waiting time for sample collection from suspect cases. These delays could have increased the risk of spread of COVID-19 infection as suspect cases were not timely tested (Kebede *et al.*, 2021).

Based on the study findings we can conclude that Supply chain management in public hospitals of Addis Ababa city was not adequately practiced in public hospitals. The public hospitals should strengthen supply chain management practices particularly logistics management and order fulfillment. Professionals having skills in supply chain management should be employed for good decision making to be achieved in public hospitals in terms of supply chain management practices. Additionally we can also concludes that, stock outs reagents, controls, machine failure, lack of sufficient personnel protective equipment's, waste disposal materials, and lack of vaccine for hepatitis B affected the reliability, safety and led to delay in timely service delivery. The noninvolvement of laboratory professionals in procurement process, and lack of training led to purchasing of equipment, reagents, consumables, that are out of specifications encouraging supplier to misbehave, which led fail to respond to quality service demands at public hospitals found in Addis Ababa, Ethiopia (Biadglign, 2019).

2.2.2 Challenges in storage and handling

Lack of adequate and standard storage space and absence of sufficient equipment including refrigerators were the main storage problems in half of medical stores in public hospitals of Addis Ababa city. In some facilities, the storage condition of medical laboratory supplies was not in compliance with standard guide line including inability of controlling room temperature and unordered arrangement of flammable, dangerous, non-functional and expired products together. There was a lack of written guidelines, adequate no of infrastructure, thermometer, and adequate training of store managers in some facilities. Even though, Laboratory personnel have indispensible role in controlling medical laboratory commodities storage, they were not involved in some medical stores. There was a lack of adequate power supply, sockets and inconsistent power sources in some stores to accommodate temperature sensitive reagents (Hussien, 2014).

Most of the study targets believed that due to the improper storage of laboratory commodities, test failure experienced in St. Paul's hospital. Storage capacity was not sufficient to maintain min-max. The testing unit, mini-store, and main store enforced to stock 1 week, 2weeks and less than 4 months maximum stock. To keep 4 months stock of cold chain commodities, the existed refrigerators was not sufficient and made to stock pharmaceutical commodities, rather for domestic products. It is known that cold chain commodities are temperature sensitive and perishable, but the refrigerators found in mini-store had no generator power supply (Bekele, 2019).

Absence of frozen temperature and stock cards, and lack of separation of flammables and corrosives for laboratory commodities were some of the limitations observed in Tikur Anbessa specialized hospital. There were stock out for longer period of time for different laboratory commodities, mainly including Chemistry, serology, Hematology and urinalysis which might have led to services interruptions. Laboratory personnel have indispensable role in inventory management of laboratory commodities storage, they were in involved in mini-stores only but not in the main hospital medical stores (Admassu, 2016).

Concerning the public hospitals in Jimma zone, most of the refrigerators in the study hospitals were not medical refrigerators, i.e., they were home/kitchen refrigerators and did not have any embedded or external monitoring devices. No data loggers were connected to evaluate the past performance of the refrigerators. The hospitals had frequent electrical interruptions, and some of them did not have a back-up generator, or the available one was of limited capacity (Befekadu *et al.*, 2020).

In a study conducted in St. Paul's millennium medical college commodities stocked were not according to the storage guideline in which there were challenges of storage space and the location of the store was not convenient for laboratory department (Bekele, 2019). Inappropriate storage facilities, a high incidence of waste, insufficient infrastructure were the main challenges of medical laboratory commodities in the public health facilities of Jimma zone (Befekadu *et al.*, 2020).

Absence of guidelines for storage of laboratory supplies and storing flammable and hazardous chemicals in specialized area; significant emergency orders, delays of supplies delivery, and absence of common tools for keeping track of laboratory reagents and ordering and receiving laboratories supplies were the problems observed in diagnostic service assessment in Tanzania (Kagaruki *et al.*, 2018).

2.2.3 Challenges in inventory management

Logistics formats in the health facilities providing viral load testing of HIV using RT-PCR technique are found to be used inadequately which causes facilities to come up with false reports like artificial stock out, stock out and over stock problems. On the other hand, the order quantity of VL/EID commodities is decided non-uniformly by different bodies at each health facilities which lead PFSA to face big problem to manage the distribution practices. In addition, facilities are not applying standard minimum and maximum stock level at all (Fozia, 2018).

In Tikur Anbessa specialized hospital there were stock out for longer period of time for different laboratory commodities, mainly including Chemistry, serology, Hematology and urinalysis which might have led to services interruptions. Laboratory personnel have indispensable role in inventory management of laboratory commodities storage, they were in involved in mini-stores only but not in the main hospital medical stores (Admassu, 2016). The study shows that in St. Paul's hospital above quarter of medical laboratory commodities was over-stocked from 4 to 36 month of stock (Bekele, 2019). A significant number of facilities were stock out for some laboratory commodities at the day of the assessment and during six months before the assessment in public health facilities of Addis Ababa city. Other challenges were failure to update bin cards and stock cards, over stock of some commodities and shortage of training for professionals on inventory management (Desale *et al.*, 2013).

Stock out, overstocking and expiries of reagents and supplies: lack of effective laboratory stock management; absence of consistency in the type of forms used by the facilities for ordering causing poor tracking systems; majority of health facilities laboratory information system was not integrated within the logistics information system due to which the laboratories missed important information to support decisions in determining orders or procurement quantity, forecasting, or monitoring system performance; significant emergency orders, delays of supplies delivery, and absence of common tools for keeping track of laboratory reagents and ordering and receiving laboratories supplies were the problems observed in diagnostic service study in Tanzania (Kagaruki *et al.*, 2018).

The public hospitals studied in Jimma zone had an ineffective inventory management system for laboratory products in which many of them had a high incidence of waste, stock out of core laboratory commodities, and frequent supply interruption of laboratory commodities from vendors. These suggest weak coordination between the players in the supply chain of laboratory items (Befekadu *et al.*, 2020).

2.2.4 Challenges in distribution and transportation

The minimum duration from placing an order to delivery ranged from one to 60 days with a significantly higher mean waiting time in public than private health facilities in Tanzania. The maximum duration from placing an order to delivery ranged from one to 180 days with a higher mean waiting time in public than private health facilities. Twelve (30.8%) HFs reported to have at least one order that took longer than usual (ranging from one to 270 days) to deliver and 10 of these (83.3%) were public facilities including seven hospitals. Inadequate funds, stock out at medical store department and transportation problems were the main reasons for delays of the deliveries to the health facilities. Majority of the laboratories (72.2%) obtained their supplies from different sources. Most of the public facilities ordered their supplies from different sources compared to private facilities (68.2% vs. 31.8) (Kagaruki *et al.*, 2018).

In most of the health facilities in Jimma zone , failure to timely arrange vehicles was the main problem of distribution and transportation (Befekadu *et al.*, 2020). Time to deliver

COVID-19 testing items to member States of 29 African countries shows that 48% of distributed laboratory testing commodities for COVID-19 delivered in 3 days or less; 30% of the testing commodities delivered between 4-10 days and the rest 22% of testing commodities delivered above 10 days (Kebede, 2020).

2.2.5 Challenges in human resource management

Lack of trained manpower capable of performing the molecular biology experiments (e.g. viral RNA extraction and qPCR) required for testing SARS- CoV-2 and interpreting the results is one of the major limitations in the testing and confinement of COVID-19 in developing countries. For the few laboratory experts present in these countries, priority is given to other medical emergencies (e.g. heart attacks, road accidents). We suggest that training and workshops directed to COVID-19 testing and organized at a national and international level will be helpful in generating the necessary skilled manpower. The invitation of trained volunteers from the international community could be another option; however, in the scenario of a global epidemic and lockdown, receiving such rapid help from the international community is unlikely. Alternatively, the available manpower could learn from the expertise of the international community by video, audio, and other user-friendly tools and checklists developed by WHO and other international organizations, to make the process fast and efficient (Giri and Rana, 2020a).

There was also a challenge in public hospitals in Jimma zone in addressing skills deficits through short-term training. As a result, it was difficult for most workers to decide how much, when, and how to order laboratory products. One of a store person illuminated as follows (Befekadu *et al.*, 2020).

In Senegal one of the main challenges faced during the COVID-19 pandemic is personnel needed for effective testing. To insure the availability of enough personnel there was a continuous recruitment process and training (Banda, 2022). Risk of mortality is much higher in developing countries with poor scientific and inadequate trained manpower are other barriers to the fight against the virus in the developing world (Giri and Rana, 2020b). From Ethiopian experience one of the critical challenges we are facing is the inadequate well-trained human capital in terms of sample collection and delivery, testing and test result dispatching (Mulu *et al.*, 2021).

There is a well-designed logistics system for laboratory commodities and majority of persons responsible in managing commodities in main store (pharmacy store) were trained in LMIS. Majority of laboratory mini-store managers and laboratory managers didn't get LMIS training (Desale *et al.*, 2013). Even though, Laboratory personnel have indispensible role in controlling medical laboratory commodities storage, they were not involved in some medical stores (Hussien, 2014). In Tikur Anbessa hospital laboratory personnel have indispensable role in inventory management of laboratory commodities storage, they were in involved in mini-stores only but not in the main hospital medical stores (Admassu, 2016).

The non-involvement of laboratory professionals in procurement process, and lack of training led to purchasing of equipment, reagents, consumables, that are out of specifications encouraging supplier to misbehave, which led fail to respond to quality service demands at public hospitals found in Addis Ababa, Ethiopia (Biadglign, 2019). The public hospitals in Jimma zone studied had absence of supportive training in laboratory logistics (Befekadu *et al.*, 2020).

From the project assessment result knowledge gap, lack of in-service training on LMIS, less work experience of laboratory professionals and not knowing about the commodity inventory and consumption mechanism were the main findings. The result also shows, the study populations have different knowledge on the commodities imbalance (which means the stock out, under stock and over stock) frequency Additionally, laboratory department was not conducting supervision in the store, using standard check list for stock status and storage condition formally (Muhe, 2015).

Even though health facilities providing viral load testing service using PCR technique are equipped with relatively adequate number of qualified staff, there is a big gap in the employees' skill because of lack of continuous and up-to date training. On the other hand, the order quantity of VL/EID commodities is decided non-uniformly by different bodies at each health facilities which lead PFSA to face big problem to manage the distribution practices (Fozia, 2018).

Many LICs and MICs countries are prevented from scaling-up their COVID-19 testing programmes using manual PCR testing due to facing constraints related to the need for highly trained specialized laboratory technicians (United Nations Children’s Fund, 2020). The management of laboratory inventory was done by various health workers in hospitals of Tanzania; some without adequate laboratory qualifications. This is likely to be due to inadequate number of trained laboratory staff (Kagaruki *et al.*, 2018).

2.2.6 Challenges in logistics management information system

In public health facilities of Addis Ababa city there is a well-designed logistics system for laboratory commodities and majority of persons responsible in managing commodities in main store (pharmacy store) were trained in LMIS. Majority of laboratory mini-store managers and laboratory managers didn't get LMIS training. A significant number of facilities were stock out for some laboratory commodities at the day of the assessment and during six months before the assessment. Utilization of the logistics recording and stock/bin cards usage were limited to the higher level facilities such as regional health bureaus and hospitals (Desale *et al.*, 2013).

Logistics formats in the health facilities providing viral load PCR testing in Ethiopia are found to be used inadequately which causes facilities to come up with false reports like artificial stock out, stock out and over stock problems. In addition, facilities are not applying standard minimum and maximum stock level at all (Fozia, 2018). Absence of integration logistics management information system with laboratory information system were the main findings in Saint Paul's Hospital Millennium Medical College (Muhe, 2015).

Absence of consistency in the type of forms used by the facilities for ordering causing poor tracking systems; majority of health facilities laboratory information system was not integrated within the logistics information system due to which the laboratories missed important information to support decisions in determining orders or procurement quantity, forecasting, or monitoring system performance (Kagaruki *et al.*, 2018).

The absence of standard ordering systems for different laboratory commodities made the inconsistent flow of information, which in turn caused financial decisions difficult. How much to request for some products depended on previous consumption data, the number of tests carried out, and stock out of laboratory supplies. Besides, the order pattern for these different commodities is often variable. Despite the use of the Health Commodity Management Information System (HCMIS) program, issues remain due to the reasons mentioned above. Additionally, failure of the staff in updating data in HCMIS was another bottleneck, though the health facilities received continuous support from a partner, AIDS-free project (Befekadu *et al.*, 2020)

2.2.7 Public-private partnership in medical laboratory

The status and realities in the existing health system in Ethiopia calls for collaboration with the private health sector which should be informed by appropriately designed public-private partnership model. It was found out that while the public health sector in Ethiopia as well as Addis Ababa is severely resource-constrained, which calls for active involvement of non-state actors, the private health sector is not properly incorporated into the health system. This dissertation argues that the policies, legal and regulatory frameworks of the incumbent government and the Addis Ababa City Government in particular do not provide adequate room for the development of PPPs in the health service delivery. The study also discovered that the existing institutional framework and capacity of the public sector is not adequate and appropriate to manage both the existing and future PPP initiatives in the health sector of Addis Ababa (Hurissa B., 2016)

Tanzania has an advanced policy environment for public-private collaboration in the health sector. The 1994 proposals for health sector reforms highlighted the need for the public sector to effectively engage with the private sector in order to improve delivery of health services in Tanzania. These proposals were adopted and have been integrated in a number of health sector policies and strategies. The country's National Health policy of 2003 explicitly states that public and private actors will jointly mobilize and share resources for the efficient delivery of well-regulated health services while ensuring accountability to the public. The health policy of 2007 also acknowledges the contribution of the private sector in health service provision. The important role that PPPs play in the health sector is also emphasized in the country's strategic plans for the health sector, which highlights the effective operationalization and enhancement of PPPs for the provision of health and nutrition services as strategic focus areas. In 2008, the Ministry for Health and Social Welfare appointed a national PPP steering committee whose role is to promote effective PPPs, with the specific objectives of coordinating stakeholders, formulating and refining service agreements between government and service providers, and addressing all legal requirements for PPPs (Ravishankar and Lehmann, 2015)

In contrast to the highly developed health policy environment for PPPs, the legal framework for PPPs in Tanzania requires greater refinement. With the exception of the private hospital act and private health laboratories act, most of the laws neither articulate the role of the private sector nor provide for their engagement. However, recent reviews of health legislation in the country propose to expressly empower specific government authorities to establish and sustain PPPs for the purpose of improving services to the people. Despite a supportive policy environment and an improving legal environment, actual implementation and use of PPPs remains low. This is especially the case with partnerships involving private for-profit entities. In contrast, the Government of Tanzania has a very close relationship with the private not-for-profit sector. The Ministry of Health has a long history of service-level agreements with FBO facilities which are called schemes of service, wherein the government provides a range of inputs including infrastructure, equipment and commodities, while the private partner provides human resources and management of the facility or vice versa. An estimated 40 percent of districts in Tanzania have a “designated district referral hospital” that is run by a FBO. Another example of a successful PPP in Tanzania is the support that the Abbott Fund has provided the Government for modernizing laboratories and mentoring laboratory staff. Apart from these arrangements, however, formal PPPs in the health sector, especially with respect to laboratory services, are few (Ravishankar and Lehmann, 2015).

Equipment placement contracts for laboratory equipment in public facilities were started in Kenya by Roche and Becton, Dickinson and Company, and have now spread to other countries in the region. While other forms of written PPP arrangements related to laboratory services are not widespread, Kenya offers several examples of public-private collaboration. The two largest private health providers, Aga Khan and Nairobi Hospital, are officially not-for-profit private enterprises and are therefore beneficiaries of public subsidies. There are agreements for quality control and training between public sector entities and specialized private providers. Finally, there is considerable collaboration between private and public entities for service delivery within vertical health sector programs for TB and HIV/AIDS through initiatives like Kenya Association for the Prevention of TB and Lung Diseases (KAPTLD) that can be considered formal, despite not being signed on paper. Some respondents saw the provision of TB cultures for multi-drug resistant TB testing as a promising avenue for partnerships, as the National TB Laboratory is struggling with a high workload, and there are two private hospitals that are able to offer TB culture services (Ravishankar and Lehmann, 2015).

Supporting PPPs is a key component of Vision 2030, Government of Kenya's long-term national development roadmap. A PPP Bill was passed in 2012. The Ministry of Heath has a PPP Unit that is meant to provide leadership and guidance in fostering PPPs in the health sector. Several respondents noted that historical mistrust from decision-makers in the public sector towards the private sector seems to have dwindled, and two existing dialogue platforms, PPP Health Kenya and the TB PPP Mix, bring together public and private sector actors. Outside the laboratory sector, the Ministry of Health has MoUs with FBO health facilities, primarily related to the seconding of health professionals to these facilities. In addition, there are several MoUs between private training institutions and public health facilities to enable internships for trainees. Respondents in Kenya were hopeful that with the new government structure and the PPP framework in place, more PPPs would emerge and prosper in the future (Ravishankar and Lehmann, 2015)

Uganda has a history of memoranda of understanding (MoU) between the government and faith-based facilities. Typically, the national Ministry of Health has signed agreements with the umbrella organizations for FBOs such as the Uganda Protestant Medical Bureau, Uganda Catholic Medical Bureau and Uganda Muslim Medical Bureau, whilst MoUs with health facilities are often signed at the district-level between district officials and individual faith-based facilities. Beyond such arrangements, formalized public-private partnerships are rare, although some respondents considered the provision of emergency healthcare to the population, which private facilities are constitutionally obliged to do, as a form of PPP. There are several successful placement arrangements involving Mulago National Referral Hospital, central public health laboratories, regional referral hospitals, and FBO hospitals. Despite the limited use of formal PPPs currently, they are widely seen as an important vehicle for improving the quality and scope of public services in the future. PPPs are officially part of the government's strategy as highlighted in the current health sector strategic and investment plan (Ravishankar and Lehmann, 2015)

Rwanda, having a reputation for efficiency and the Government of Rwanda enacting a new policy to leverage the private sector to spur development, international firms are interested in investing in the country. The Rwanda Development Board has a key role in supporting and enabling investment, and more generally in building a favorable market climate. Making Rwanda a destination for medical tourism by 2020 is a key component of the Board's vision for the health sector. Despite the Government's recognition of the important role the private health sector and strong political will at the highest levels of Government to engage the private sector, the implementation of PPPs in the health sector is moving slowly (Ravishankar and Lehmann, 2015).

It is found that 90.6% of the respondents reported that public private partnerships have resulted to the availability of medicines, medical devices and medical equipment (health commodities) whereas 82% of respondents reported transportation services as also the main contribution of PPPs in HSCM in Rwanda. Similarly, almost 80 % of respondents reported that the PPPs have improved the cost effectiveness in treatment of diseases (e.g. availability of hepatitis C medicines at a lower cost). More than three quarters (77.4%) of the respondents agreed that PPPs have resulted to the improved financing of health supply chain projects, while (62.6%) of the total number of the study interviewed reported that PPPs in HSCM contributed to availability of health infrastructure (Byomuhangi *et al.*, 2021).

Most of the respondents indicated that they did not have guidelines or procedures in place for managing implementation of PPPs. PPP projects in health supply chain management meet their expected results The majority of the respondents indicated that the PPPs projects in HSCM met their expected results during implementation and this represented 72% of the respondents. Most of the respondents representing 95 % agreed that there were impediments in the execution of PPPs Projects. The respondents showed that there was a challenge of insufficient information sharing between public and private and this was representing 83.7%. Another major issue was complex procurement requirements for medical products and equipment by public institutions in private sector representing 73.3% of the respondents. Ineffective management/coordination and clear roles and responsibilities between public institutions and key stakeholders were also another issue that was reported by 67.6% of the respondents. The challenges of contracts including delay payment, clauses favoring one part etc. was pointed out to be hindering the implementation of PPPs in HSCM representing 64.8% of the respondents. The least issue reported was lack of regulations/laws about PPPs in HSCM representing 58.1 % of the respondents (Byomuhangi *et al.*, 2021)

PPPs in supplying Non Communicable Diseases medicines, & PPPs with Abbott in distribution of laboratory reagents for Viral Load, Biochemistry & Hematology that contributed a lot for health public. Others said leasing of medical equipment where health facilities do purchase only the reagents. Others said that successfully implemented collaboration between District Pharmacies and private health posts by putting them under the same conditions as other public health facilities for example during active distribution where they transport health commodities for them together with those of the health centres they belong to. PPP in regards with health supply chain management is a key approach to increase supply chain performance through readily health commodity availability, accessibility and affordability to the public (Byomuhangi *et al.*, 2021).

This study investigated the different interventional areas of PPPs existing in HSCM in Rwanda. These PPP areas include Finance, Maintain, Operate & Deliver, Design and Build. The most predominant PPP area was, the delivery of health commodities, representing 99 %. Other areas were the supply of IT supplies and equipment (operate) (53%), the finance area (52%) the maintenance area (40%), designing of projects (35%) and build area, construction of health facilities/buildings (31%). It was found that the private institutions had the mainly in charge for; providing financial support or co-financing the capital cost or project, maintenance of buildings and equipment required to offer health supply chain management services, organization and provision of specific HSCM services; delivery of equipment, the design of the facilities, building of new, or renovation of existing, buildings. Benefits of PPPs in HSCM in Rwanda From the results of this study, the respondents revealed that there were benefits of using PPPs in HSCM in Rwanda. The benefits that the respondents indicated were availability of health commodities (90.6%), transportation services involved in HSCM (82%), cost effectiveness to patients in relation to their treatment (80%) (Byomuhangi *et al.*, 2021).

In Rwanda for instance, the PPPs have led to cost effectiveness to patients and services were made accessible, available and affordable to the patients and hence real sense of cost effectiveness to patients as a result of PPPs. The GOR also has done tremendous efforts in implementing PPPs in HSCM especially in the availability of health commodities at affordable cost, there has been also signing agreement between GOR with private companies in construction of health facilities for instance, health posts that have been build country wide especially in remote areas (Byomuhangi *et al.*, 2021)

2.2.8 Testing service delivery of COVID-19

During the process of laboratory testing expansion for COVID-19 in Ethiopia some key challenges were faced in which a weak supply chain management for laboratory reagents and supplies was a major concern. As a result, there were interruptions in COVID-19 testing, back logs of untested samples and prolonged waiting time for sample collection from suspect cases. These delays could have increased the risk of spread of COVID-19 infection as suspect cases were not timely tested (Kebede *et al.*, 2021).

Like almost all countries in Africa, Ethiopia did not have the capacity to test for COVID-19 at the onset. Samples were initially transported for testing to the National Institute for Communicable Diseases (NICD) Laboratory in South Africa, a WHO regional reference laboratory. With support from WHO and the Africa Centres for Disease Control and Prevention, EPHI set up the National Influenza and Arbo-viruses Reference Laboratory as the first COVID-19 testing laboratory in the country by 7 February 2020. Capacity building for laboratory technicians was conducted and donations of COVID-19 detection and extraction kits and reagents were made. The COVID-19 IMS set up by Federal Ministry of Health and led by the Minister of Health Source consisted of 18 pillars with subunits. Based on their expertise, individuals were appointed to lead and coordinate readiness and response activities under each pillar. Global Health continued to support external quality control testing with samples shipped to NICD. Expansion of COVID-19 laboratory testing sites to the regional states was ramped up early in the response through the pre-existing laboratory network with regional public health laboratories, universities and laboratories under the Ministry of Agriculture (Lanyero *et al.*, 2021)

The primary goal of severe acute respiratory syndrome coronavirus type 2 (SARS- CoV-2) testing is to reduce the spread of coronavirus disease 2019 (COVID-19). Due to the highly infectious nature of SARS-CoV-2, there is an urgent need for a fast turnaround of results to institute preventative measures such as the isolation of confirmed cases and contact tracing. Currently, reverse transcription polymerase chain reaction (RT-PCR) tests are the gold standard for diagnosing COVID-19. The laboratory equipment required to perform RT-PCR is often lacking in resource-limited settings, hindering the fast and accurate detection of SARS-CoV-2 in diagnostic laboratories. It is revealed that stock outs of diagnostic tests were caused by problems in procurement, inventory management, storage, distribution and quality assurance (Maluleke *et al.*, 2021).

Collection and testing of biological samples from patients meeting the suspected case definition for COVID-19 are critical for proper monitoring and control of disease infection in the community. The WHO has recommended the testing of COVID-19 infection using a reverse transcription polymerase chain reaction (RT-PCR)-based protocol to target different viral genes. However, these testing protocols require RNA extraction kits, costly RT (quantitative) -PCR machines and trained technicians to operate them. These resources are limited in countries with poor scientific infrastructure, such as Nepal, where there was only one laboratory equipped to test for coronavirus infection, with an increase to three planned for the end of March 2020. The establishment of fully equipped testing laboratories that fulfill WHO guidelines would require huge investment, expertise and time, which are currently limited by the COVID-19 crisis. Alter- native testing protocols that allows COVID-19 testing with limited resources and available manpower in the country, will be highly useful in the fight against the COVID-19 pandemic (Giri and Rana, 2020a).

Diagnostics play a key role in the prevention of spread of COVID-19 as they enable rapid identification of infected individuals so that public health measures can be implemented. Extensive and systematic testing as guided by surveillance objectives is essential to contain the pandemic and is the only way countries, if they act early, can avoid extensive and economically crippling repeated lockdowns. Monitoring of genetic changes in SARS CoV-2 is critical in rapidly identifying new viral variants that may have altered or enhanced biological properties which may affect transmissibility, pathogenesis or severity of infection. Diagnostic capacity, including with recently introduced RDTs needs to be scaled up to increase research and development efforts in detecting and understanding SARS CoV-2 impact on the public health response strategy. Countries should continue to strengthen and sustain domestic diagnostic and laboratory capacity to manage large-scale testing for SARS-CoV-2 at national and sub-national levels, while building on and maintaining the established infrastructure and diagnostic capacity for other relevant diseases (WHO, 2021).

Countries should continue to strengthen and sustain domestic diagnostic and laboratory capacity to manage large-scale testing for SARS-CoV-2 at national and sub-national levels, while building on and maintaining the established infrastructure and diagnostic capacity for other relevant diseases (WHO, 2021).

The global nature of the COVID-19 pandemic has led to an acute and drastic shortage of some essential supplies, including diagnostics. The coordinated efforts by the global health community improved availability of manual PCR tests for low income countries and middle income countries that are currently estimated to be approaching the capacity of those countries to consume them. However, the availability of automated PCR tests for high-throughput platforms and, even more so, of POC PCR tests remains critically limited for LICs and MICs Many countries are prevented from scaling-up their COVID-19 testing programmes using manual PCR testing due to facing constraints related to cold chain requirements, central laboratory settings, the need for highly trained specialized laboratory technicians, amongst others (United Nations Children’s Fund, 2020).

The WHO strongly recommends testing of suspects for COVID-19 and the individuals who have been in contact with them in order to control the infection in a community. However, due to the high infectivity of the virus and lack of appropriate resources (e.g., testing laboratories, kits), most of the world is struggling to contain the spread of corona virus and is facing an increasing number of fatalities. Risk of mortality is much higher in developing countries with poor scientific and health infrastructure such as Nepal and these countries are struggling to test for and track the infection due to a lack of laboratory facilities and trained manpower. Lack of equipped diagnostics with appropriate instruments and testing kits and safety information are among other barriers to the fight against the virus in the developing world (Giri and Rana, 2020b).

2.3 Conceptual frame work

2.3.1 Study Variables

The study variables include both dependent and independent variables. In this study the independent variables include challenges of storage condition and handling, challenges of inventory management, challenges of distribution and transportation , challenges of human resource management , challenges in public-private partnership and challenges of logistics information management system. The dependent variable is the delivery of COVID-19 PCR testing service.

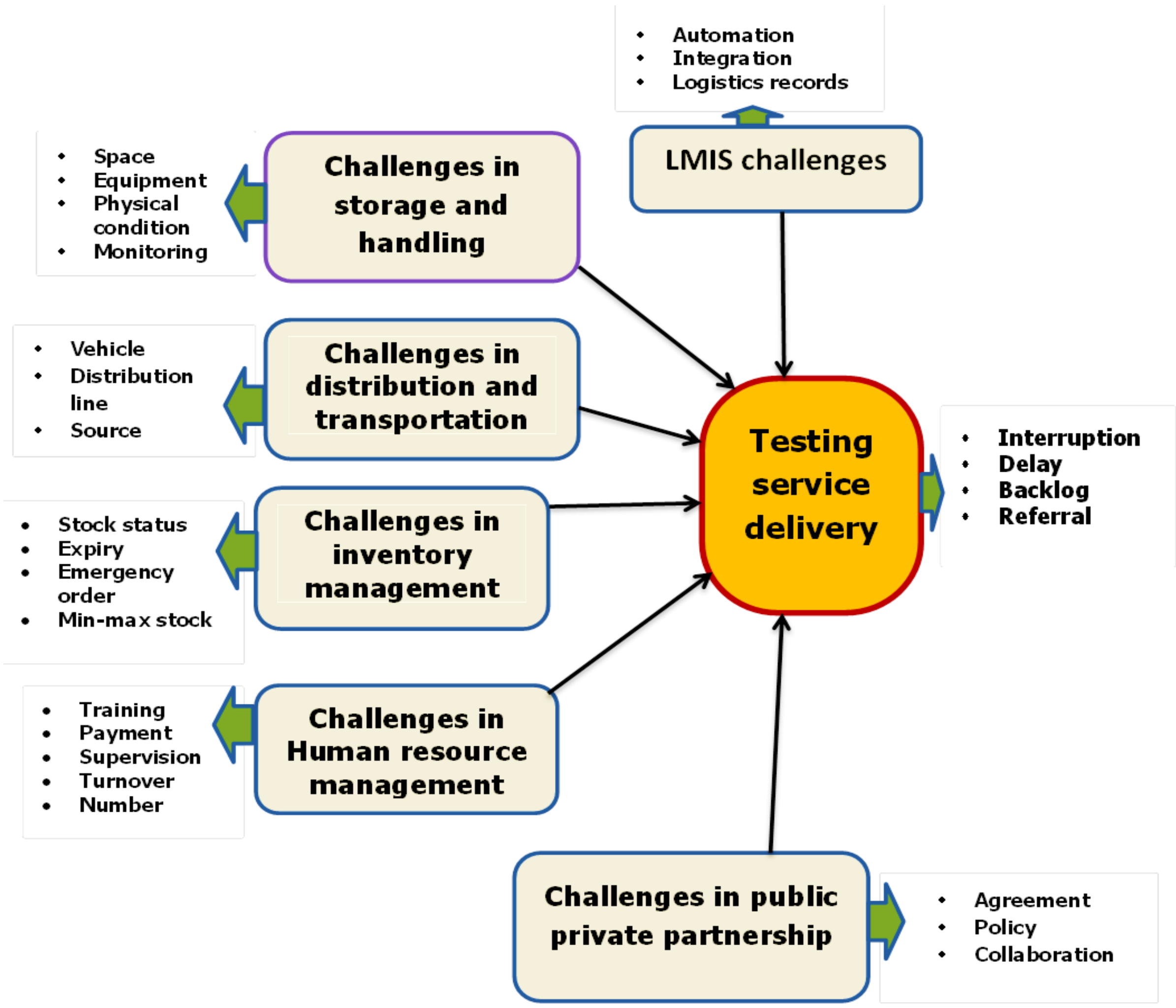


Fig 2.2 Conceptual frame work (self-work, 2022)

Chapter 3

Methodology

3.1 Description of the study area

Addis Ababa, the capital city of Ethiopia, is the largest city with projected estimated population of about 3,774,000 according to central statistical agency's 2021 reports and estimated geographical area of 540 sq. km. It is administratively sub-divided into 11 sub cities. The city is a home for vast variety health facilities ranging from clinics, health centers, diagnostic laboratories, primary hospitals, general hospitals, referral hospitals, specialized hospitals to public health research institutes.

The study area is chosen due to the fact that most of the COVID-19 testing service in Ethiopia, using the PCR technique, is done in the city and so does most of the supply chain activities for COVID-19 testing reagents.

3.2 Research approach

Research approaches are plans and the procedures for research that span the steps from broad assumptions to detailed methods of data collection, analysis, and interpretation. The selection of a research approach is based on the nature of research problem or issue being addressed, the researchers' personal experiences, and the audiences for the study. A research approach can be qualitative, quantitative or mixed approach. Often the distinction between qualitative research and quantitative research is framed in terms of using words (qualitative) rather than numbers (quantitative), or using closed-ended questions (quantitative hypotheses) rather than open-ended questions (qualitative interview questions). Mixed methods research is an approach to inquiry involving collecting both quantitative and qualitative data, integrating the two forms of data. The core assumption of this form of inquiry is that the combination of qualitative and quantitative approaches provides a more complete understanding of a research problem than either approach alone (Creswell, 2014).

In this study both quantitative and qualitative approaches (mixed approach) are employed to collect the required data about the challenges in the supply chain management of COVID-19 PCR testing reagents.

3.3 Research design

Designing of the research is done mainly to solve the problem of getting the various stages of the research under control. This control factor is very important for the researcher during any of the research operation. Preparation of the design for the research forms a very critical stage in the process of carrying out some research work or a research project. Research Design in general terms can be referred to as the scheme of work to be done or performed by a researcher during the various stages of a research project. With the help of the research design, one can very easily handle and operate research work as research design acts as a working plan, which is made by a researcher even before he starts working on his research project. By this, researcher gets a great help and guidance in achieving his aims and goals (Bhome, Jha and Chandwani, 2013). A research design is simply the framework or plan for a study that is used as a guide in collecting and analyzing the data. It is a blueprint that is followed in completing a study. Research design is the blue print for collection, measurement and analysis of data. Actually it is a map that is usually developed to guide the research (Valunaite Oleskeviciene and Sliogeriene, 2020)

A facility based cross-sectional descriptive and explanatory study was conducted in the selected facilities and a semi-structured questionnaire was administered to professionals responsible for managing COVID-19 PCR testing reagents at the selected health facilities for the purpose of obtaining the desired data. Both closed and open-ended questions were used to collect the required information. Questions were adopted from assessment tool for laboratory Services and supply chains (ATLAS), Logistics system assessment tool (LSAT) as well as from different literatures and modified based on the objective of the research.

3.4 Population and sampling design

3.4.1 Population of the study

The study population comprises public health facilities in Addis Ababa which were participating in providing PCR COVID-19 testing service during the time of data collection including hospitals, diagnostic laboratories, regional laboratories and public health research institutes. At the time of data collection there were 26 health facilities providing COVID-19 PCR testing service in Addis Ababa.

3.4.2 Sampling

Census sampling method was used since the study population has a small size that can be included in the sample totally in selecting the health facilities. The population size includes 26 health facilities in Addis Ababa city currently providing COVID-19 PCR testing service. From each health facility providing COVID-19 PCR testing two health professionals, i.e. laboratory head and one professional responsible for supply chain management of the reagents, were included in the study using purposive sampling. So the total sample size was 52 health professionals from the health facilities.

3.5 Data source and types

To collect the required information both primary and secondary sources of data were used as a source of information.

3.5.1 Primary data

Primary data was collected by using semi-structured questionnaire to be filled by professionals who are responsible for the supply chain management of the reagents.

3.5.2 Secondary data

Secondary data was collected from logistics records and documents found in the selected COVID-19 PCR testing health facilities.

3.6 Data collection instrument

A semi-structured questionnaire with both closed and open ended questions adapted from LIAT and ATLAS was used to collect the data required. Questions were modified in to five point Likert scale to meet the objectives of the study and quantitative data collected using the instrument. Open ended questions were also adopted from the mentioned sources and other sources based on which qualitative data was collected after modifying the questions according to the study requirements.

3.7 Data collection procedure

A semi-structured questionnaire was distributed to the selected health facilities in the city of Addis Ababa to be filled by the professionals who are currently engaged in the supply chain activities of COVID-19 PCR testing reagents; medical laboratory department head and one additional professional responsible for supply chain management of the reagents.

3.8 Ethical consideration

Before conducting the research all parties which are targets of the study were commenced and a letter informing the facilities administrators was written from Addis Ababa university school of commerce. The participants were asked first for their consent to participate and were told that any privacy related issue will be treated carefully in such a way that no their names and their facility names will not be written but number codes will be used instead. A effort was also made to inform participants that there will be a high degree of confidentiality during data collection and no name of any selected health facility and participating professionals will be put in the findings instead the aggregate result of the facilities and summary results will be projected.

3.9 Data analysis

After being checked for completeness the quantitative data was checked for completeness first. Then it was coded, entered in to and analyzed using SPSS (statistical package for the social sciences) version 23 software from which descriptive statistics generated describing the challenges and result presented using tables. To analyze the effect of independent variables on the dependent variable regression analysis (multi-linear regression analysis) was used since the independent variables were ordinal while the dependent variable was continuous scale. The qualitative data of the study was analyzed using qualitative analysis method first by reading the collected data several times followed by transcribing the data, categorizing the data, reducing and finally writing the final report by narrating the finding.

The multi linear regression equation used for the analysis is:

$$\mathbf{Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + e}$$

Where:

Y= Average duration of service interruption

X_1= Distribution and transportation challenge

X_2= LMIS challenge

X_3= Storage and handling challenge

X_4= Inventory management challenge

X_5= public–private partnership challenge

X_6= Human resource management challenge

β_0, β_1, β_2, β_3, β_4, β_5, β_6 are the regression equation coefficients for each independent variable

3.10 Reliability and validity

To insure the validity of the instrument utilized for collecting the needed information questions were adopted from LIAT and ATLAS and other publications after which it was modified based on the objectives of the study. The prepared questionnaire was pretested by distributing samples and feedback obtained from professionals in the study population.

To check reliability Cronbach's alpha coefficient was calculated and a result obtained which is in an acceptable range as shown in the table. Cronbach's alpha coefficient greater than 0.9 indicates excellent, 0.8-0.89 good, 0.7-0.79 acceptable, 0.6 -0.69 questionable, 0.5-0.59 poor and if less than 0.5 unacceptable reliability level (George and Mallery, 2003)

Table 3.1 Reliability Statistics

Variables	Number of items	Cronbach's alpha
Challenges in distribution and transportation	5	.723
Challenges in LMIS	10	.75
Challenges in storage and handling	18	.722
Challenges in inventory management	11	.755
Challenges in public private partnership	6	.802
Challenges in human resource management	7	.824
Challenges in testing service delivery	5	.757

Therefore the data is reliable since the value of Cronbach's alpha is greater than 0.7 as it can be seen from the above table.

Chapter 4

Results and discussions

This chapter deals with the analysis, presentation, interpretation and discussion of the data collected using a semi structured questionnaire from the target population. SPSS (statistical package for social sciences) version 23 was used to analyze the data collected and present the findings in the form of tables and graphs. Using SPSS descriptive statistics was generated to describe the characteristics of the variables and presented in the form of tables. Additionally multi linear regression analysis was done to measure the predictors' effect on the dependent variable and result presented in the form of tables and graphs. The results obtained were finally interpreted statistically.

4.1 Response rate

From the target population of 52 respondents in the health facilities participating in COVID-19 PCR testing only 46 respondents from the health facilities have responded positively by to be included in the study which constitutes 88.46 % of the target population. In contrast 6 respondents; constituting 11.54 % of the target population, have not responded by stating they are too busy and have no time to fill the questionnaire even maximum effort is used to convince them.. Our review of the literature reveals that there is no agreed upon minimum response rate. Baruch and Holom (2008) reported that response rate in business and management research could be anywhere between 50% and 80%, with an overall average of 55.6% (Gravetter and Wallnau, 2012). Therefore the response rate of 88.46 % is acceptable.

4.2 Demographic profiles of the respondents

Respondents were asked demographic questions including age, work experience, educational level, level of facility they are working in, ownership of facility they are working in, wok experience on COVID-19 and their profession to assess their demographic profiles.

Table 4.1 Facility ownership

Facility ownership		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Governmental	12	26.1	26.1	26.1
	Private	34	73.9	73.9	100.0
	Total	46	100.0	100.0	

Source; Field survey data, 2022

As it can be seen from table 4.1 most of the respondents were from private health facilities that constitute about 74 percent while the remaining 26 percent of the respondents were from public health facilities.

Table 4.2 Demographic profiles of the respondents

Items	Categories	Frequency	Percent	Valid Percent	Cumulative Percent
Profession	Medical laboratory	45	97.8	97.8	97.8
	Pharmacy	1	2.2	2.2	100.0
	Total	46	100.0	100.0	
Sex of respondents	Male	33	71.7	71.7	71.7
	Female	13	28.3	28.3	100.0
	Total	46	100.0	100.0	
Educational level	BSc degree	42	91.3	91.3	91.3
	MSc	4	8.7	8.7	100.0
	Total	46	100.0	100.0	
Work experience	1-5 years	6	13.0	13.0	13.0
	5.1-10 years	30	65.2	65.2	78.3
	>10years	10	21.7	21.7	100.0
	Total	46	100.0	100.0	
Level of facility	Research institute	10	21.7	21.7	21.7
	Hospital	17	37.0	37.0	58.7
	Regional laboratory	2	4.3	4.3	63.0
	Diagnostic center	4	8.7	8.7	71.7
	Diagnostic laboratory	13	28.3	28.3	100.0
	Total	46	100.0	100.0	
Work experience on COVID-19	Up to 1.5 Years	13	28.3	28.3	28.3
	> 1.5 Years	33	71.7	71.7	100
	Total	46	100.0	100.0	

Source: Field survey data, 2022

Table 4.2 shows that almost all of the professionals working in the supply chain management of COVID-19 PCR testing reagent are medical laboratory professionals constituting 97.8 percent which is a good practice except one professional being pharmacist. Male professionals are greater in number being 71.7 percent while female professionals are 28.3 percent. It also shows that percent of the professionals working on supply chain management of COVID-19 PCR reagents are holders of bachelor degree and the remaining 8.7 percent are masters' degree holders.

Furthermore most of the professionals (65.2 percent) have a work experience of 5.1 up to 10 years, 21. 7 percent of them have work experience of more than 10 years while the rest 13 percent have a work experience of less than five years. When we see the level of facilities where the respondents work; hospitals constitute the largest number followed by diagnostic laboratories, research institutes, diagnostic center and regional laboratory respectively. Finally it shows that most of the respondents have an experience of more than 1.5 years in COVID-19 testing service as shown from the table indicting most of them have good work experience on COVID-19 testing service..

4.3 Supply Chain Challenges of COVID-19 reagents at the Health Facilities in Addis Ababa

This section presents descriptive analysis results of the challenges in supply chain management of COVID-19 PCR reagents including challenges in distribution and transportation, challenges in storage and handling, challenges in inventory management, challenges in LMIS, challenges in human resource management , challenges in public-private partnership and challenges in testing service availability. Descriptive statistics such as frequencies, mean, grand mean and standard deviations are used to describe these challenges.

In the tables of descriptive statistics abbreviations are used where:

M= Mean
St.D = Standard deviation
SD = strongly disagree
D= Disagree
N=Neutral
A= Agree

SA= strongly agree

4.3.1 Challenges of distribution and transportation of the COVID-19 reagents

To assess the challenges of distribution and transportation of the COVID-19 PCR reagents in the health facilities five questions were asked focusing on sources or suppliers of COVID-19 PCR reagents, challenge of access to a vehicle, occurrence of delay in assigning vehicles to transport COVID-19 reagents, challenge in getting adequately refrigerated vehicles to transport cold chain reagents and presence of established distribution system for COVID-19 PCR reagents.

Table 4.3 Challenges of distribution and transportation of the COVID-19 reagents

Ser. No	Challenges of distribution and transportation	Response categories					M	St.D
		SD	D	N	A	SA		
1	The COVID-19 PCR reagents come from different sources or suppliers	2	6	15	18	5	3.39	1
2	The laboratory has a challenge of access to a vehicle	1	9	13	15	8	3.43	1.068
3	There is a delay in assigning vehicles to transport COVID-19 reagents	1	10	15	15	5	3.28	1.004
4	There is a challenge in getting adequately refrigerated vehicles to transport cold chain reagents	1	2	9	22	12	3.91	.915
5	There is no established distribution system for COVID-19 PCR reagents for all levels	2	4	16	15	9	3.46	1.149
Grand mean							3.49	1.03

Source: Field survey data, 2022

Table 4.3 shows that 23(50 percent) respondents agreed on the challenge that COVID-19 PCR reagents come from different sources or suppliers; 23 (50 percent) respondents agree on the challenge of access to vehicle; 20 (43.5 percent) respondents agree on the challenge that there is a delay in assigning vehicles to transport COVID-19 reagents; 36(78.3 percent) respondents agreed on the challenge getting adequately refrigerated vehicles to transport cold chain reagents ; 24 (52.2 percent) respondents agree on the challenge that there is no established distribution system for COVID-19 PCR reagents for all levels. From the respondents with disagreement on the presence of the challenges, delay in assigning vehicles to transport COVID-19 reagents has a number of 11 (23.9 percent) respondents which is the highest. The mean scores also shows the level of agreements to the presence of the challenges in which all have a score greater than the mid-point. The overall mean of the distribution and transportation challenge is 3.49 which is above the mid-point showing the respondents agreement to the presence of the challenges.

Qualitative data analysis results from open ended questions show that the main challenges in distribution and transportation of COVID-19 PCR reagents found are limited number of refrigerated vehicles to transport cold chain reagents and weak commitment of higher officials in governmental health facilities. In private health facilities the main problem indicated is the transportation of reagents with cold condition requirements in cartoons using ice instead of refrigerated vehicles. This shows the relevance of the descriptive and qualitative data analysis results.

4.3.2 Challenges of storage and handling of the COVID-19 reagents

Respondents were asked 18 questions focusing on storage condition, availability of required equipment, training of store man, warehouse automation, sufficiency of the storage area to handle the required amount of reagents, physical status of storage area, the way reagents are arranged and availability and periodic checkup of logistics formats and guidelines.

Table 4.4 Challenges of storage and handling

Ser. No	Challenges of storage and handling	Response categories					M	St.D
		SD	D	N	A	SA		
1	Reagents are stored together with flammables and corrosives.	17	13	12	3	1	2.09	1.050
2	There is no separation of damaged and/or expired reagents from usable products	20	15	9	2	0	1.72	.779
3	There is no a standard guideline for the storage and handling of COVID-19 PCR reagents	5	17	18	5	1	2.5	.837
4	Fire safety equipment is not available and	18	15	11	2	0	1.93	.904

	accessible							
5	There is no consistent power supply and backup generator	15	16	11	4	0	2.09	.962
6	Products are not protected from direct sunlight at all times of the day	26	16	3	1	0	1.54	.721
7	Roof is not always maintained in good condition to avoid sunlight and water penetration.	24	17	4	1	0	1.61	.745
8	The current space and organization is insufficient for existing reagents and reasonable expansion	2	3	9	21	11	3.78	1.031
9	There is a problem of cold storage capacity to handle the desired quantity of cold chain reagents	1	6	9	22	8	3.65	.994
10	There is no frozen storage for reagents which require frozen condition	8	10	14	8	6	2.87	1.276
11	Refrigerator is not cleaned and deforested when it needs	18	18	9	1	0	1.85	.816
12	There is no thermometer for controlling cold chain temperature	23	21	2	0	0	1.54	.585
13	There is no thermometer for controlling room temperature	22	17	6	1	0	1.7	.785
14	Temperature chart is not up-to-date	24	17	4	1	0	1.61	.745
15	Refrigerator temperature is not recorded daily	25	18	3	0	0	1.52	.623
16	Freezer temperature is not recorded daily	20	15	10	1	0	1.85	.918
17	Products are not stored and organized in a manner accessible for first-to-expire, first-out (FEFO) counting and general management.	8	20	15	2	1	2.30	.891
18	There is no adequate training for store man on the storage characteristics of COVID-19 PCR reagents	5	8	11	14	8	3.26	1.255
Grand mean							2.19	.884

Source; Field survey data, 2022

It is shown that the main challenges in storage and handling are insufficiency of the current space and organization for existing reagents and reasonable expansion, inadequacy of cold storage capacity to handle the desired quantity of cold chain reagents and inadequate training for store man on the storage characteristics of COVID-19 PCR reagents with mean score of 3.78, 3.65 and 3.26 respectively. The overall mean of the storage and handling challenges is 2.19 which indicate most respondents disagree to the presence of the challenges.

Qualitative data results shows that in public health facilities the storage and handling challenges are the shortage of refrigerators to handle the reagents when large amount of reagents is received; inadequacy of the storage space to handle the required amount of reagents; reagent leakage problems; shortage of training for those working in store and problem in maintaining storage condition of reagents. When we come to private health facilities shortage of storage space, poor monitoring of reagents storage condition, and mix up of reagents in refrigerator were the challenges stated by the respondents. In addition to this a challenge in getting consistent power supply and reagent expiry due to low testing volume at periods of low COVID-19 prevalence in some governmental health facilities is occurred.

4.3.3 Challenges of inventory management of the COVID-19 reagents

To assess the main challenges in inventory management of the COVID-19 testing reagents respondents were asked eleven questions focusing on occurrence of stock out of reagents, reagent expiry, over stock of reagents, emergency order of reagents, redistribution of reagents, inventory control procedure, periodic review of stock level, disproportioning of reagents and involvement of non-laboratory professionals to determine resupply quantities.

Table 4.5 Challenges in inventory management

S. No	Challenges in inventory management	Response categories					M	St.D
		SD	D	N	A	SA		
1	Experience emergency orders of COVID-19 PCR reagents	0	1	9	29	7	3.91	.631
2	There is occurrence of stock out of COVID-19 PCR reagents	4	5	10	18	9	3.5	1.188
3	There is occurrence of over stock of COVID-19 PCR reagents	14	15	11	6	0	2.2	1.025
4	There is occurrence of expiry of COVID-19 PCR reagents	9	11	13	11	2	2.7	1.171
5	There are no written provisions for the redistribution of over stocked reagents	0	3	11	23	9	3.83	.801

6	There is no a policy of storing and issuing stock according to FEFO inventory control procedure	9	21	8	5	3	2.39	1.125
7	Damaged and expired reagents are not removed from stock records at all levels	9	19	14	4	0	2.28	.886
8	The laboratory has not a set of minimum and maximum stock level for COVID-19 PCR reagents	5	8	10	18	5	3.22	1.191
9	Stock level of COVID-19 PCR reagents is not reviewed periodically	6	18	12	9	1	2.59	.983
10	Resupply quantities are determined by non-laboratory professionals	6	10	10	18	2	3.00	1.155
11	The is disproportioning of reagents during distribution	2	5	12	21	6	3.52	1.005
Grand mean							3.01	1.01

Source; Field survey data, 2022

According to table 4.5 the challenges of experiencing emergency orders of COVID-19 PCR reagents, absence of written provisions for the redistribution of over stocked reagents, disproportioning of reagents received during distribution and the occurrence of stock out of COVID-19 PCR reagents are the main challenges in inventory management with a mean score of 3.85, 3.74, 3.52 and 3.5 respectively. 35(76.1 percent) of the professional have agreed that they experience emergency orders: 30 (65.22 percent) agreed on the absence of written provisions for redistribution of overstocked reagents; 27 (58.7 percent) agreed on the occurrence of stock out of reagents and 27 (58.7 percent) agreed on the disproportioning of reagents during distribution. The overall mean of the inventory management challenges is 3.01 which is above midpoint indicating the agreement of most respondents to the presence of the challenges.

Qualitative data results show that stock out of reagents in both public and private health facilities including stock out of VTM, controls, detection kit and extraction kit was the main problem faced. Apart from this public health facilities faced problems in ranging from disproportioning of reagents, overstock of few reagents such as PCR reaction plate and receiving unordered reagents from central distribution site while private health facilities were facing challenges in training staff as needed , receiving near expire dated reagents as well as disproportioning of reagents. In addition to this a challenge of reagent expiry due to low testing volume at periods of low COVID-19 prevalence in some governmental health facilities is occurred.

4.3.4 Challenges of the COVID 19 Reagents Supply chain Human resource management

Challenges in human resource management of COVID-19 testing supply chain were assessed by asking the respondents seven questions focusing on shortage of professionals, adequacy of training, turnover of professionals, and availability of incentive and adequacy of supervision by higher organization.

Table 4.6 Challenges in human resource management

Ser. No	Challenges in human resource management	Response categories					M	St.D
		SD	D	N	A	SA		
1	There is shortage of trained professionals working on supply chain management.	3	2	15	17	9	3.59	1.066
2	No adequate training is given on the logistics of COVID-19 PCR reagents for those working on logistics.	1	3	7	23	12	3.91	.939
3	No adequate training is given on the logistics of COVID-19 PCR reagents for those working on COVID-19 testing.	4	7	8	19	8	3.43	1.205
4	Incentive is not given for those working on COVID-19	5	14	12	9	6	2.93	1.218
5	There is turnover of professionals working on COVID-19 PCR testing	3	13	11	11	8	3.17	1.217
6	There is turnover of professionals working on COVID-19 PCR reagents supply chain management	7	12	11	11	5	2.89	1.251
7	There is no adequate supervision by higher organization on COVID-19 testing	2	7	14	17	6	3.39	1.043
	Grand mean						3.33	1.13

Source; Field survey data, 2022

Table 4.6 shows that the main challenges in human resource management for COVID-19 PCR reagent supply chain are inadequacy of training given on the logistics of COVID-19 PCR reagents for those working on logistics, inadequacy of training given on the logistics of COVID-19 PCR reagents for those working on COVID-19 testing, shortage of trained professionals working on supply chain management, and absence of adequate supervision by higher organization on COVID-19 testing with corresponding mean scores of 3.91, 3.61, 3.59, and 3.39 respectively which are above the mid-point. 35(76.1 percent) respondents agree on the inadequacy of training given to those working on logistics, 28(60.9 percent) respondents agree on the inadequacy of training given to those who are working on COVID-19 PCR testing, 26(56.52 percent) agree on the shortage of trained professionals working on the supply chain management and 23(50 percent) respondents agree on the inadequacy of supervision by higher organization. The overall mean is 3.33 showing that most of the respondents agreed to presence of the challenges.

Qualitative data results also show that in human resource management of COVID-19 testing reagents supply chain challenges such as inadequate training of staff, inadequate number of staff, turnover of professionals, inadequate payment and interference of nonprofessional personnel were the main challenges in private health facilities. Poor communication of human resource with staff, inadequate number of employees and unsatisfactory payment were the problems found.

4.3.5 Challenges of logistics information management system in the COVID-19 Reagents

To assess the challenges in logistics management information system respondents were asked ten questions focusing on availability of logistics forms, ordering and receiving reagents, integration of the LMIS with laboratory management information system, automation of the logistics management information system, logistics management information management system report and availability of consumption data

Table 4.7 Challenges in logistics information management system

Ser. No	Challenges in logistics information management system	Response categories					M	St.D
		SD	D	N	A	SA		
1	There is a challenge in the availability of forms used to keep track of reagents in stock	9	18	14	4	1	2.35	.971
2	There is a delay in receiving reagents after being ordered	0	8	16	15	7	3.46	.959
3	The logistics management information system is not integrated with the laboratory management information system	3	7	6	19	11	3.61	1.201

4	Summaries of consumption data are available	8	18	12	8	0	2.43	.981
5	Warehouse activities are not automated	1	6	12	14	13	3.70	1.093
6	The logistics management information system report does not include Stock on hand	23	17	5	1	0	1.65	.766
7	The logistics management information system report does not include quantities used	23	19	3	1	0	1.61	.714
8	The logistics management information system report does not include losses and adjustments	14	16	12	4	0	2.13	.957
9	The logistics management information system is not automated	1	5	12	19	9	3.65	.994
10	There is a delay in sending reports to the higher level	12	17	12	5	0	2.22	.964
Grand mean							2.68	.960

Source; Field survey data, 2022

The challenges of warehouse activities non- automation, the non-automation of the whole logistics management information system, non-integration of the logistics management information system with the laboratory management information system and the occurrence of delay in receiving reagents after being ordered are the main challenges the major challenges with a mean score of 3.7, 3.65, 3.61 and 3.46 respectively in the logistics information management system of COVID-19 PCR reagents. The overall mean of LMIS challenges is 2.68 showing that most of the respondents haven't agreed to the presence of the problems.

Furthermore qualitative data results show that at both governmental and private health facilities conducting COVID-19 PCR testing of the logistics management information system being not automated, non-accessibility of internet access and inadequate training in LMIS to staff are the main challenges given by respondents. In few governmental health facilities COVID-19 testing reagents logistics management is not being treated as that of other laboratory reagents including problems in bincard and stock card arrangements was indicated.

4.3.6 Challenges of Public-Private relationship in the COVID 19 Reagents supply chain

Respondents were asked six questions to assess the challenges in public-private partnership focusing on sharing of reagents, availability of policies, availability of agreement, training of professionals, referral system and integration of the logistics system between public and private facilities as shown in table 4.8.

Table 4.8 Challenges in public-private relationship

Ser. No	Challenges in public-private relationship	Response categories					M	St.D
		SD	D	N	A	SA		
1	There is no sharing of COVID-19 PCR reagents between public and private health facilities with regard to this facility	1	4	9	21	11	3.80	.980
2	There is no policy prepared for Public-private partnership in this facility	0	1	11	22	12	3.98	.774
3	There is no agreement signed between public and private facilities in this facility	0	0	16	20	10	3.87	.749
4	There is no tool used for integrating COVID-19 PCR testing reagent logistics between private and public facilities	0	5	8	23	10	3.83	.902
5	There is no collaboration between public and private in training professionals on COVID-19 testing and its logistics	0	5	11	24	6	3.67	.845
6	There is no established referral system between public and private facilities on COVID-19 testing in this facility	0	8	5	25	8	3.72	.958
Grand mean							3.81	.868

Source; Field survey data, 2022

Table 4.8 shows that all the challenges in public private partnership have greater mean scores and most of the respondents agreed to the presence of the challenges. This shows that the public-private partnership in supply chain management of COVID-19 reagents between public and private health facilities is weak. The overall mean of 3.81 for public-private partnership challenges indicates that most respondents agreed to the presence of the challenges.

Qualitative data results also show that in most of the public and private health facilities there is no clear communication on public-private partnership. It is also characterized by poor relationship and weak collaboration in the supply chain management of COVID-19 PCR testing reagents according to comments of respondents.

4.4 The Situation of Covid-19 testing service delivery at the Health facilities in Addis Ababa

To assess the testing service availability of COVID-19 testing respondents were asked four Likert scale type questions focusing on the problems of testing service availability. Frequency of occurrence of challenges was used as a measure for problems including occurrence of service interruption of covid-19 testing, delay in COVID-19 testing, occurrence of backlog of untested samples and referral of samples to other COVID-19 testing sites as shown in table 4.9.

Additionally average duration of testing service interruption was computed from maximum and minimum duration of service interruption. To determine average duration of service interruption respondents were asked for maximum duration of service interruption and minimum duration of service interruption after which their sum was averaged. Summary of the result was generated using SPSS as presented in the table 4.10.

Table 4.9 Challenges in Covid-19 testing service delivery

Ser. No	**Challenges in Covid-19 testing service delivery**	**Response categories**					**M**	**St.D**
		Never	**Rarely**	**Sometimes**	**Often**	**Always**		
1	Experience service interruption of covid-19 testing	0	26	20	0	0	2.44	.786
2	Experience delay in COVID-19 testing	6	22	18	0	0	2.26	.681
3	Experience backlog of untested samples	18	22	6	0	0	1.74	.681
4	Experience referral of samples to other COVID-19 testing sites	15	15	16	0	0	2.02	.830
Grand mean							2.16	.744

Source; Field survey data, 2022

Table 4.10 Average duration of COVID-19 testing service interruption

Statistics

Average duration of service interruption

N	Valid	46
	Missing	0
Mean		3.0598
Median		3.1250
Std. Deviation		.85177
Range		3.50
Minimum		1.00
Maximum		4.50

Source; Field survey data, 2022

For the challenges in testing service delivery more than half of the respondents replied that there is service interruption, delay in COVID-19 testing, and backlog of untested reagents and referral of sample for testing to other testing sites in which the frequency of the problem may be rarely or sometimes which is a great challenge in fighting the pandemic. The overall mean is 2.16 showing that most facilities were facing challenge in testing service delivery at least rarely.

Qualitative data results from open ended questions on testing service availability show that public health facilities were facing problems such as interruption in providing testing service, elongated turnaround time of result delivery and backlog of untested client samples waiting for test.

4.5 The Effect of Supply Chain Challenges on the COVID-19 testing services delivery of health facilities in Addis Ababa

Multi linear regression was used to measure the effect of independent variables (distribution and transportation challenge, LMIS challenge, storage and handling challenge, inventory challenge, public private partnership challenge and human resource management challenge) on the dependent variable of testing service delivery challenge measured by duration of testing service interruption in days. The following assumption tests were done for multi linear regression as a precondition.

4.5.1 Assumption tests

4.5.1.1 Test of Linearity

To test the linearity of the relationship between independent variables (distribution and transportation challenge, LMIS challenge, storage and handling challenge, inventory challenge, public private partnership challenge and human resource management challenge) and dependent variable (average duration of service interruption) a scatter plot was generated for each independent variable paired with the dependent variable using SPSS version 23. As it can be seen from appendix I, all independent variables have linear relationship with the dependent variable.

4.5.1.2 Test of normality

For a normal distribution to occur there should not be deviation from normality. A significant value (Sig. less than .05) indicates a deviation from normality (Field A., 2009).

Table 4.11Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	Df	Sig.
Challenges in distribution and transportation	.109	46	.200*	.962	46	.135
Challenges in LMIS	.125	46	.070	.969	46	.253
Challenges in storage and handling	.146	46	.094	.948	46	.139
Challenges in inventory management	.158	46	.056	.922	46	.714
Challenges in public private partnership	.136	46	.032	.945	46	.082
Challenges in human resource management	.114	46	.169	.954	46	.052
Average duration of service interruption	.132	46	.043	.957	46	.085

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Source; Field survey data, 2022

Table 4.16 shows that the significance values for Shapiro-Wilk statistics; recommended when sample size is less than 100, are greater than 0.05 making them insignificant. This shows that there is no significant deviation from normality. Therefore the data is normally distributed.

4.5.1.3 Test for Multicollinearity

Multicollinearity exists when there is a strong correlation between two or more predictors in a regression model. Variance inflation factor less than 10 and tolerance greater than 0.1 indicates that Multicollinearity is not a problem in a model (Field A., 2009)

Table 4.12 Test for Multicollinearity

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	-3.759	.762		-4.936	.000		
	Challenges in distribution and transportation	.593	.182	.359	3.264	.002	.490	2.039
	Challenges in LMIS	.092	.220	.037	.417	.679	.747	1.338
	Challenges in storage and handling	.036	.254	.014	.142	.888	.616	1.624
	Challenges in inventory management	.615	.221	.327	2.782	.008	.429	2.331
	Challenges in public private partnership	.501	.205	.241	2.443	.019	.607	1.647
	Challenges in human resource management	.229	.202	.124	1.130	.265	.495	2.019

a. Dependent Variable: Average duration of service interruption

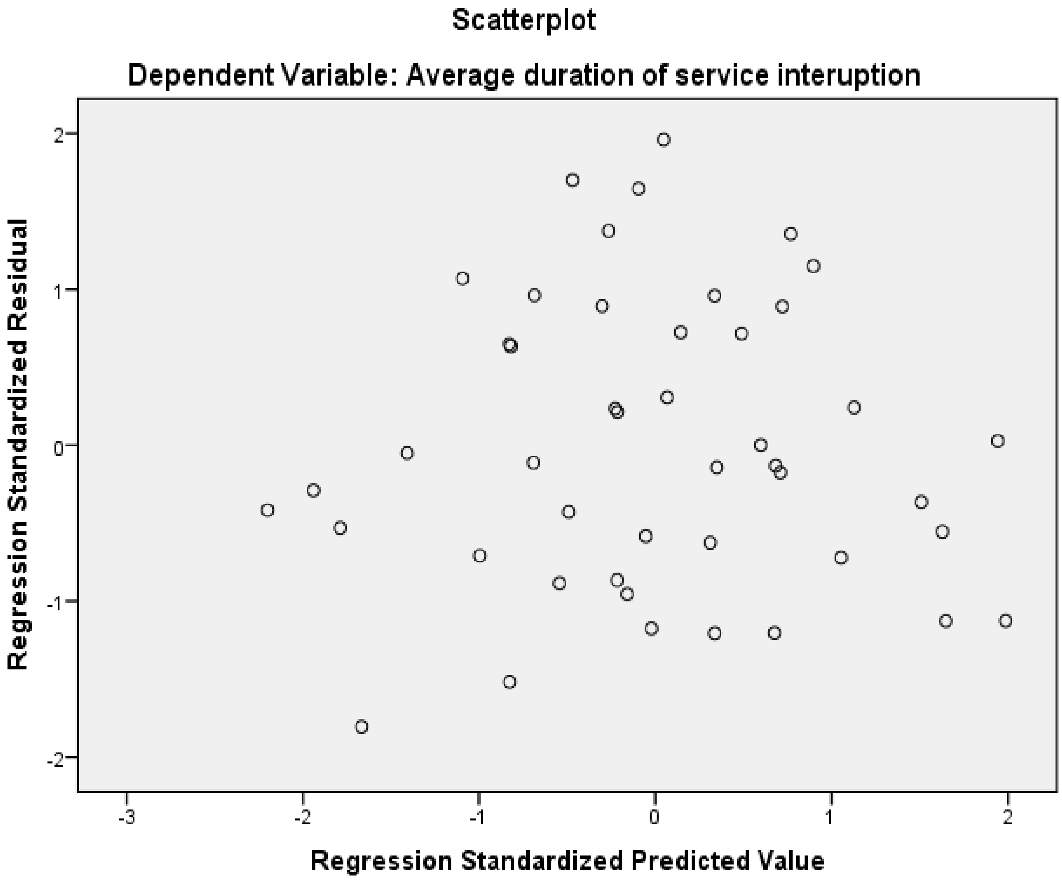
Source; Field survey data, 2022

To check that there is no Multicollinearity problem the tolerance and VIF values were computed as shown above. Since the tolerance values are > 0.1 and the VIF values are < 10 which indicates there is no Multicollinearity problem.

4.5.1.4 Test of homoscedasticity

At each level of the predictor variable(s), the variance of the residual terms should be constant. This just means that the residuals at each level of the predictor(s) should have the same variance (homoscedasticity); when the variances are very unequal there is said to be heteroscedasticity (Field A. 2009)

Figure 4.1 Test of homoscedasticity



Source; Field survey data, 2022

As it can be seen from the plot there is no pattern in the data showing homoscedasticity is met.

4.5.1.5 Independent errors

For any two observations the residual terms should be uncorrelated (or independent). This eventuality is sometimes described as a lack of autocorrelation. This assumption can be tested with the Durbin–Watson test, which tests for serial correlations between errors. Specifically, it tests whether adjacent residuals are correlated. A value from 1 to 3 is considered good

(Field A., 2009). Therefore residual terms are uncorrelated in the model since Durbin–Watson value in table 4.18 is 1.246.

4.5.2 Multi linear regression result

Table 4.13 model summary

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.877[a]	.769	.734	.43947	1.246

a. Predictors: (Constant), Challenges in human resource management, Challenges in LMIS, Challenges in storage and handling, Challenges in distribution and transportation, Challenges in public private partnership, Challenges in inventory management

b. Dependent Variable: Average duration of service interruption

Source; Field survey data, 2022

R square, multiple coefficient of determination, can be interpreted as the proportion of the variability in the dependent variable that can be explained by the several independent variables in the model (Joe F. Hair, 2020) From the model summary above the value of R2 Indicates that 76.9 % of the change in the dependent variable (duration of serve interruption) is due to the changes in the dependent variables (distribution and transportation challenge, LMIS challenge, storage and handling challenge, inventory challenge, public private partnership challenge and human resource management challenge).

Table 4.14 ANOVA

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	25.116	6	4.186	21.674	.000[b]
	Residual	7.532	39	.193		
	Total	32.648	45			

a. Dependent Variable: Average duration of service interruption

b. Predictors: (Constant), Challenges in human resource management, Challenges in LMIS, Challenges in storage and handling, Challenges in distribution and transportation, Challenges in public private partnership, Challenges in inventory management

Source; Field survey data, 2022

The first step in examining the overall regression model is to see whether it is statistically significant. We do this using the F statistic. To be considered statistically significant, a rule of thumb is there must be <0.05 probability that the results due to chance. (Joe F. Hair, 2020). The ANOVA statistics in table 4.19 shows that the regression model had a significance level of < 0.001% which shows that it's less than the value of significance (P-value) 0.05%; indicating the model fits to predict the change in dependent variable from the independent variable.

Table 4.15 coefficients

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	-3.759	.762		-4.936	.000		
	Challenges in distribution and transportation	.593	.182	.359	3.264	.002	.490	2.039
	Challenges in LMIS	.092	.220	.037	.417	.679	.747	1.338
	Challenges in storage and handling	.036	.254	.014	.142	.888	.616	1.624
	Challenges in inventory management	.615	.221	.327	2.782	.008	.429	2.331
	Challenges in public private partnership	.501	.205	.241	2.443	.019	.607	1.647
	Challenges in human resource management	.229	.202	.124	1.130	.265	.495	2.019

a. Dependent Variable: Average duration of service interruption,

Source; Field survey data, 2022

Therefore the regression equation becomes:

Average duration of service interruption = $-3.759 + .593X_1 + .092X_2 + .036X_3 + .615X_4 + .501X_5 + .229X_6 + e$

Where **X_1, X2, X3, X_4 X_5 and X_6 are** Challenges in distribution and transportation Challenges in LMIS, Challenges in storage and handling, Challenges in inventory management, Challenges in public private partnership and Challenges in human resource management

Regression coefficients tell us how much of the variance in the dependent variable is explained by the independent variable (Joe F. Hair, 2020). These coefficients describe the average amount of change in Y (dependent variable), given a unit change in the independent variable (Xi) being examined. From the table it can be seen that Challenges in distribution and transportation, Challenges in inventory management and Challenges in public private partnership significant predictors of the average duration of service interruption since they have a significance value < 0.05 making them statistically significant. Challenges in LMIS, Challenges in storage and handling and Challenges in human resource management have positive relation with the dependent variable but they are statistically insignificant in predicting average duration of service interruption.

Based on the coefficients in the table above; a unit change in challenges in distribution and transportation increases average duration of service interruption by 0.593; a unit change in challenges of inventory management increases average duration of service interruption by 0.615 and a unit change in challenges of public private partnership increases average duration of service interruption by 0.501.

4.5.3 Hypothesis testing

Significance, or statistical significance, describes a decision made concerning a value stated in the null hypothesis. When the null hypothesis is rejected, we reach significance. When the null hypothesis is retained, we fail to reach significance. When the p value is less than 5% ($p < .05$), we reject the null hypothesis. When the p value is greater than 5% ($p > .05$), we retain the null hypothesis. The decision to reject or retain the null hypothesis is called significance. When the p value is less than .05, we reach significance; the decision is to reject the null hypothesis. When the p value is greater than .05, we fail to reach significance; the decision is to retain the null hypothesis (Gravetter and Wallnau, 2012)

Table 4.16 Summary of hypothesis testing

	Hypothesis	Sig.	Test Result/ Decision
1	H1: Challenges in distribution and transportation have a significant effect on the average duration of COVID-19 testing service interruption of Health Facilities in Addis Ababa.	0.002	Accepted
2	H2: Challenges related with the storage and handling of the reagents has a significant effect on the average duration of COVID-19 testing service interruption of Health Facilities in Addis Ababa.	.888	Rejected
3	H3: Challenges related with inventory management of the reagents has a significant effect on the average duration of COVID-19 testing service interruption of Health Facilities in Addis Ababa.	.008	Accepted
4	H4: Challenges of human resource management of professionals responsible to the logistics of the reagents has a significant effect on the average duration of COVID-19 testing service interruption of Health Facilities in Addis Ababa.	.265	Rejected
5	H5: Challenges in the logistics information management system being utilized for managing the reagents supply chain has a significant effect on the average duration of COVID-19 testing service interruption of Health Facilities in Addis Ababa.	.679	Rejected
6	H6: Challenges in public-private relationship in the supply chain system has a significant effect on the average duration of COVID-19 testing service interruption of Health Facilities in Addis Ababa.	.019	Accepted

4.6 Discussion

This study was conducted in health facilities of Addis Ababa only due to financial and financial and time constraints which can be considered as a limitation, even though most of the COVID-19 PCR testing in Ethiopia was done in the city. Another limitation of the study was the absence of adequate number of literatures in the study area.

4.6.1 Challenges of distribution and transportation of the COVID-19 reagents

Based on the findings from descriptive statistics, the overall mean score of these challenges is 3.49 indicating that most of the respondents have agreed to the presence of the challenges. From the multi linear regression results distribution and transportation challenges have positive and significant effect on duration of testing service interruption with a beta coefficient of .593 and p value of .002 (< 0.05). This indicates that keeping other things constant a unit change in distribution and transportation challenge causes the average duration of service interruption increased by .593 units. Challenge in getting adequately refrigerated vehicles to transport cold chain reagents, absence of well established distribution system for COVID-19 PCR reagents, challenge of access to a vehicle and reagents received from different sources were the main challenges in distribution and transportation. This is comparable with previous study results from Tanzania and Ethiopia. In Tanzania transportation problems were the main reasons for delays of the deliveries to the health facilities. Majority of the laboratories (72.2%) obtained their supplies from different sources (Kagaruki *et al.*, 2018). In most of the health facilities in Jimma zone , failure to timely arrange vehicles was the main problem of distribution and transportation (Befekadu *et al.*, 2020).

4.6.2 Challenges of storage and handling of the COVID-19 reagents

The overall mean score of Challenges of storage and handling of the COVID-19 reagents is 2.19 according to the data generated using SPSS indicating that most of the respondents have disagreed to the presence of the challenge. This challenge have a positive effect on the average duration of service interruption but its effect is statistically insignificant with a beta coefficient of .036 and p value of .888 (>.05). This indicates that keeping other things constant a unit change in storage and handling challenge causes the average duration of service interruption increased by .036 units. The main challenges in storage and handling are insufficiency of the current space and organization of storage area for existing reagents and reasonable expansion, inadequacy of cold storage capacity to handle the desired quantity of cold chain reagents and inadequate training for store man. This is comparable with previous studies in Addis Ababa which is similar with previous study in Addis Ababa. According to Hussien (2014), lack of adequate and standard storage space and absence of sufficient equipment including refrigerators were the main storage problems in half of medical stores in public hospitals of Addis Ababa city. There was a lack of adequate training of store managers in some facilities (Hussien, 2014).

4.6.3 Challenges of inventory management of the COVID-19 reagents

Challenges of inventory management of the COVID-19 reagents have an overall mean score of 3.01 which shows most of the respondents have agreed to the presence of the challenge. This challenge is found to have positive and statistically significant effect on average duration of testing service interruption with a beta coefficient of .615 and p value of .008 ($<.05$). This indicates that keeping other things constant a unit change in inventory management challenge causes the average duration of service interruption increased by .615 units. Challenges of experiencing emergency orders of reagents, absence of written provisions for the redistribution of over stocked reagents, disproportioning of reagents received during distribution, stock out of reagents and absence of minimum-maximum stock level were the main challenges in this area on this study. The finding is consistent with prior studies finding in Ethiopia and Tanzania. IN Tikur Anbessa specialized hospital there were stock out for longer period of time for different laboratory commodities which might have led to services interruptions (Admassu, 2016). Stock out, significant emergency orders and delays of supplies delivery were the problems observed in diagnostic service study in Tanzania (Kagaruki *et al.*, 2018).

4.6.4 Challenges of the COVID 19 Reagents Supply chain Human resource management

The overall mean score of challenges of the COVID-19 reagents supply chain Human resource management is found to be 3.33 showing that most of the respondents have agreed to the presence of the challenge. From the regression analysis it is found that human resource management challenge have positive but statistically insignificant effect on average duration of testing service interruption with a beta coefficient of .229 and p vale of .265 ($> .05$). The beta coefficient indicates that keeping other things constant a unit change in human resource management challenge causes the average duration of service interruption increased by .229 units. In this study the main challenges in this area are inadequacy of training given on the logistics, shortage of trained professionals and absence of adequate supervision by higher organization which is comparable with previous studies. Lack of trained manpower capable of performing the molecular biology experiments required for testing SARS- CoV-2 and interpreting the results is one of the major limitations in the testing and confinement of COVID-19 in developing countries (Giri and Rana, 2020a). From Ethiopian experience one of the critical challenges we are facing is the inadequate well-trained human capital in terms of sample collection and delivery, testing and test result dispatching (Mulu *et al.,* 2021). The public hospitals in Jimma zone studied had absence of supportive training in laboratory logistics (Befekadu *et al.,* 2020). From the project assessment lack of in-service training and failure of laboratory department to conduct supervision were the main challenges in Saint Paul's Hospital Millennium Medical College (Muhe, 2015).

4.6.5 Challenges of logistics information management system in the COVID-19 Reagents

Based on the findings from descriptive statistics, the overall mean score of t Challenges of logistics information management system in the COVID-19 Reagents is 2.68 indicating that most of the respondents haven't agreed to the presence of the challenges. Furthermore it is found that LMIS challenges have positive but statistically insignificant effect on average duration of testing service interruption with a beta coefficient of .092 and p value of .679(> .05). The beta coefficient indicates that keeping other things constant a unit change in logistics management information system challenge causes the average duration of service interruption increased by .092 units. The challenges of logistics management information system non-automation, non-integration of the logistics management information system with the laboratory management information system and the occurrence of delay in receiving reagents after being ordered were the main challenges in the logistics information management system from this study. Previous studies have also similar findings. Absence of integration logistics management information system with laboratory information system was the main findings in Saint Paul's Hospital Millennium Medical College (Muhe, 2015). The period between sending an order & receiving the reagents at facilities is late and non-uniform (Fozia, 2018)

4.6.6 Challenges of Public-Private partnership in the COVID 19 Reagents supply chain

The overall mean score of challenges of Public-Private partnership in the COVID-19 reagents supply chain is 3.81, the highest score from all challenges, according to the data generated using SPSS indicating that most of the respondents have agreed to the presence of the challenge. This challenge is found to have positive and statistically significant effect on the average duration of testing service interruption with a beta coefficient of .501 and p value of .019 (< .05). The beta coefficient indicates that keeping other things constant a unit change in public-private partnership challenge causes the average duration of testing service interruption increased by .501 units. The public private partnership is generally weak according to this study which is consistent with previous studies which is comparable with previous study in Addis Ababa. According to Hurissa (2016), it was found out that while the public health sector in Ethiopia as well as Addis Ababa is severely resource-constrained, the private health sector is not properly incorporated into the health system. The policies, legal and regulatory frameworks of the incumbent government and the Addis Ababa City Government in particular do not provide adequate room for the development of PPPs in the health service delivery. The study also discovered that the existing institutional framework and capacity of the public sector is not adequate and appropriate to manage both the existing and future public-private partnership initiatives in the health sector of Addis Ababa

Chapter 5

SUMMARY, CONCLUSIONS AND RECOMMENDATION

In this chapter summary of the main findings on supply chain management challenges, conclusion and recommendations will be presented

5.1 Summary of Findings

Based on the qualitative data collected the main challenges in the supply chain management of COVID-19 PCR reagents in private health facilities are inadequate number of refrigerated vehicles to transport cold chain reagents, inadequacy of the storage space to handle the required amount of reagents, the logistics management information being not integrated with laboratory information management system, non-automation of the logistics management information system, stock out of reagents, disproportioning of reagents, receiving near expiry dated reagents, inadequate number of staff, interference of nonprofessional personnel, inadequate training, absence of clear communication in public-private partnership, and interruption in testing service

In public health facilities challenges such as shortage of refrigerators to handle the required amount of reagents, inadequacy of the storage space to handle the required amount of reagents, disproportioning of reagents during distribution, inadequate training in the supply chain management of the reagents, non-automation of the logistics management information system, non-integration of the logistics management information with laboratory information management system, stock out of reagents, weak partnership with private health facilities, interruption of testing service, backlog of untested samples and delay in test result delivery were the main challenges in the supply chain management system.

From the descriptive analysis of the data the presence the main in distribution and transportation are inadequate number of refrigerated vehicles and absence of established distribution system while the main challenges in storage and handling are low capacity of cold storage and overall storage space. In LMIS, non-automation and non-integration of the LMIS with laboratory information system are the main challenges. Absence of adequate training and shortage of trained professionals in human resource management as well as experiencing emergency order, absence of written provisions for redistribution of overstocked reagents, and stock out of reagents are the main challenges. The public-private partnership is week and the descriptive statistics shows that a lot of things have to be done to alleviate the challenges.

The regression analysis results show that challenges in distribution and transportation, challenges in inventory management and challenges in public private partnership are statistically significant predictors of testing service interruption duration with positive relation that means the more challenges in predictors the more elongated will be the service interruption. Challenges in storage and handling, challenges in LMIS and challenges in human resource management positive relation with duration of testing service interruption but statistically insignificant indicating their influence is very low.

5.2 Conclusion

Based on the findings on the supply chain management challenges of COVID-19 testing reagents obtained both from the descriptive and regression analysis it can be concluded that the challenges are resulting a problem of testing service interruption which results negative impact on the fight against the pandemic. Challenges in distribution and transportation, challenges in inventory management and weak partnership between public and private health facilities and challenges in human resource management are the main challenges in the supply chain management of the reagents.

From the regression findings it is found that 76.9 percent of the service interruption duration is explained by the predictors (challenges in human resource management, challenges in LMIS, challenges in storage and handling, challenges in distribution and transportation, challenges in public private partnership, challenges in inventory management) therefore minimizing these challenges can result a great improvement in the supply chain management and in the testing service delivery.

Finally from the hypothesis testing result it can be concluded that challenges in distribution and transportation , challenges on inventory management and challenges on public-private partnership have significant effect on average duration of COVID-19 PCR testing interruption alarming that greater focus should be given to these challenges.

5.3 Recommendation

The following recommendations are suggested based on the findings of the study.

- Both Public and private health facilities have to give attention to public-private partnership because it has a great impact on the testing service availability. If there is a partnership one facility can ask for collaboration from its partner and resolve the problem or at least minimize it. Additionally a facility may be weak in operating a specific section of the supply chain system while its partner facility strong in operating that section and vice versa in which they can be benefited from the partnership to fill their weak sides.
- The government; especially ministry of health, has to participate in creating conducive environment for public-private partnership to increase the quality of health service during emergency times and decrease economical wastage due inefficient management of the reagents supply chain system.
- The health facilities have to strive to create good working environment and prepare trainings on supply chain management for their employees since a well-trained and motivated employee can play a greet role in minimizing the challenges and increasing the service quality.
- A platform should be created which is shared among all health facilities providing the testing service in which helps which reagent is stocked out, overstocked and near expiry dated and in which facility helping them to act accordingly.
- A great focus should be given to supply chain management in the health sector to improve and standardize the system in inventory management, logistics information management, distribution and transportation, human resource management, storage and handling of reagents as well as collaboration between facilities.

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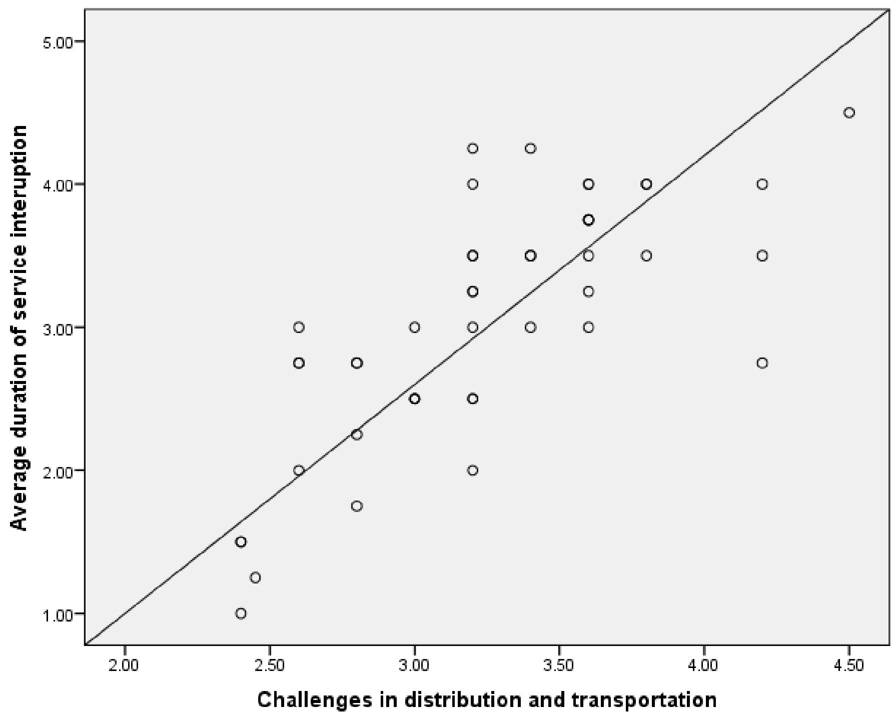
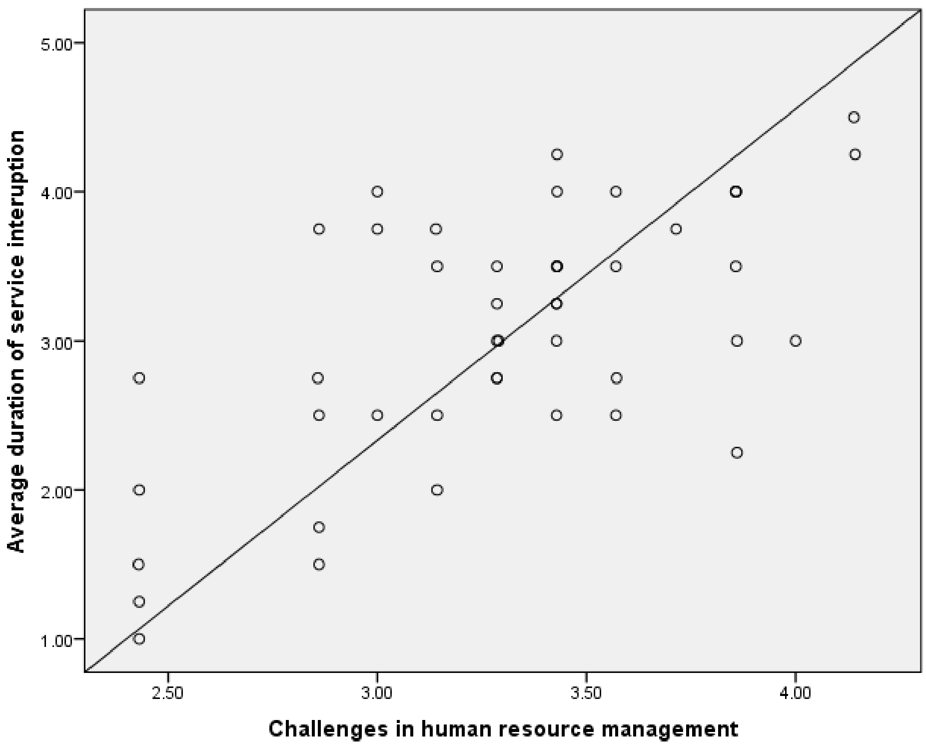
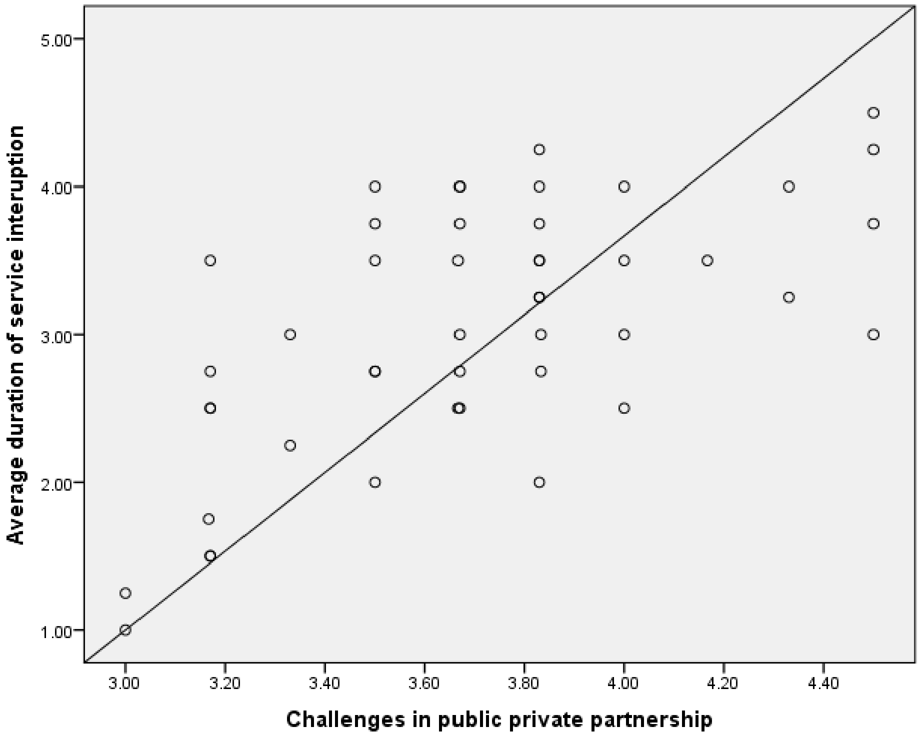
List of appendices

Appendix I

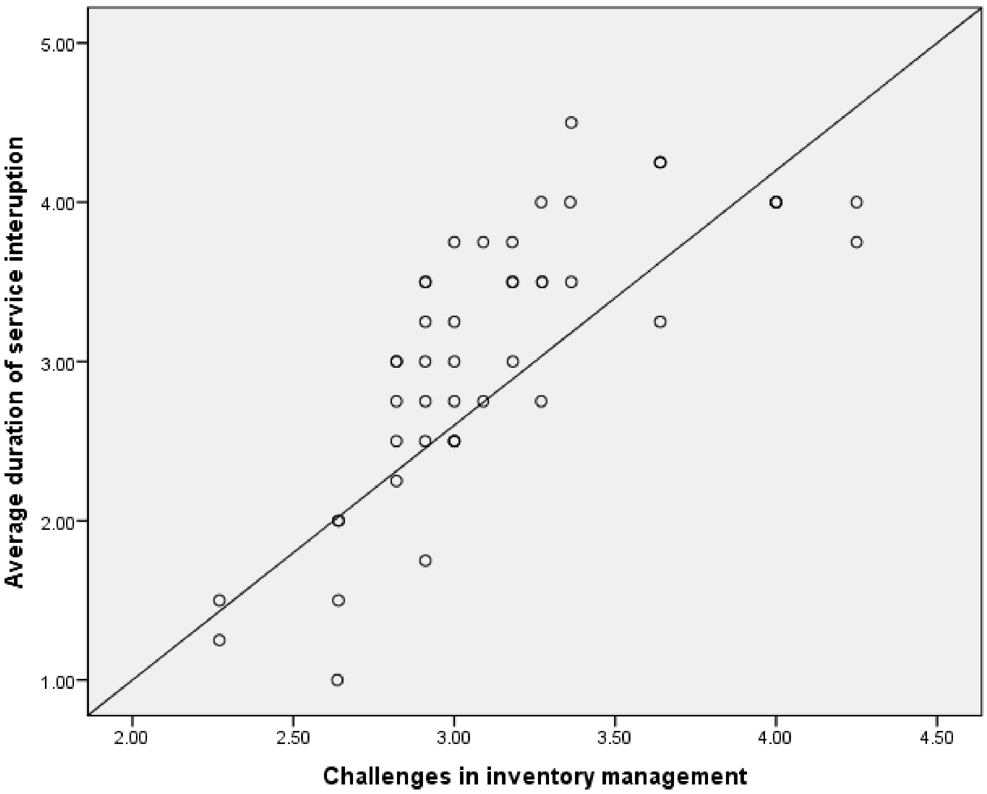
Scatter plots for linearity testing



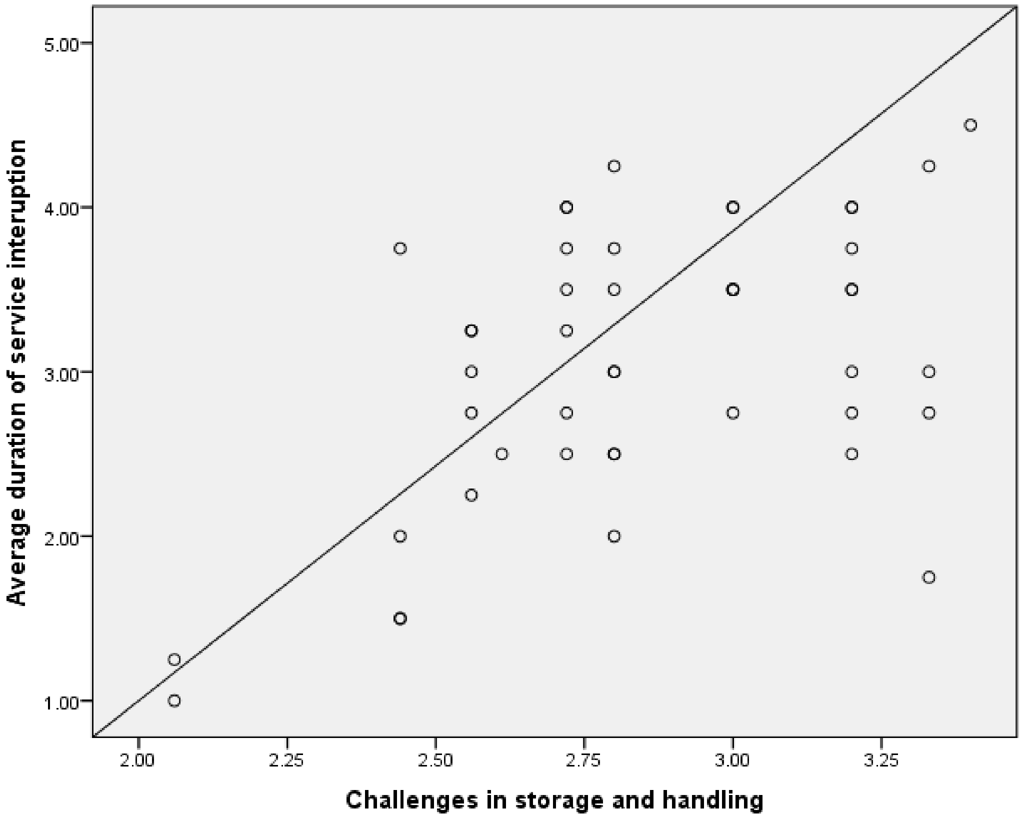


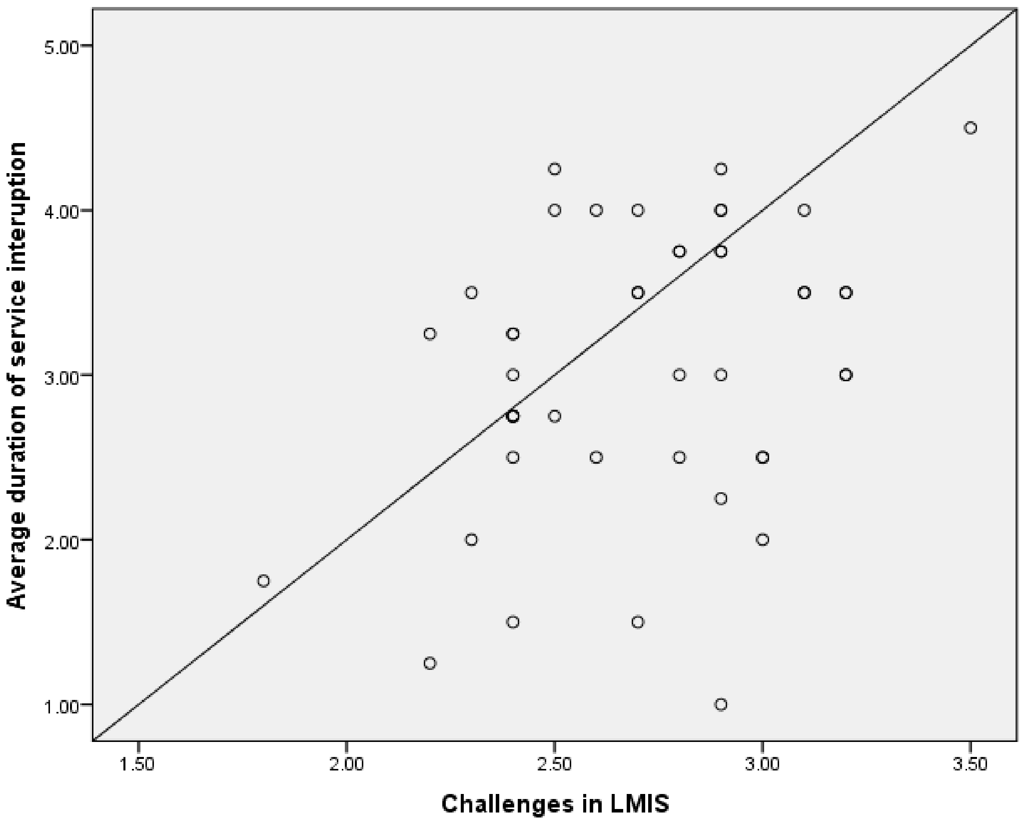


Average duration of service interuption
Challenges in public private partnership



Average duration of service interuption
Challenges in inventory management


Average duration of service interuption
Challenges in storage and handling
5.00
4.00
3.00
2.00
1.00
2.00
2.25
2.50
2.75
3.00
3.25


Average duration of service interuption
Challenges in LMIS
5.00
4.00
3.00
2.00
1.00
1.50
2.00
2.50
3.00
3.50

Appendix II

Questionnaire

Addis Ababa University

School of commerce

Department of logistics and supply chain management

Graduate program

Research title: Supply chain challenges of COVID-19 testing: the case of health facilities in Addis Ababa

My name is Kifle Teferi and I am conducting academic research for graduate program. This questionnaire is prepared as an instrument to collect the required data for the partial fulfillment of degree of Master of Arts in Logistics and Supply Chain Management.

The information collected will be used for academic purpose only and is confidential. Thank you for your willingness to give the required information by answering the following questions. When you give your answer to the questions please tick or circle the appropriate answer for choose type questions and provide your answer on the space provided for short answer questions.

General information

Date	______________________________
Ownership of facility	A. Governmental B. Private
Your profession	A. Medical laboratory B. Pharmacy C. Other (specify):__________________________
Your sex	a. Male b. Female
Educational level	A. College diploma B. BSc degree C. MSc D. Others (specify) __________________________
Work experience	Years:________ Months:________

Level of the facility	A. Research institute B. Hospital C. Regional laboratory D. Diagnostic center E. Diagnostic laboratory F. Other(specify) ___________________________
How long have you been since you start providing COVID-19 PCR testing?	_________ Years _________ Months

Part I. Distribution and transportation

Level of agreement 1= strongly disagree 2=disagree 3= neutral 4= agree 5= strongly agree						
Ser. No	Items	1	2	3	4	5
1	The COVID-19 PCR reagents come from different sources or suppliers					
2	The laboratory has a challenge of access to a vehicle					
3	There is a delay in assigning vehicles to transport COVID-19 reagents					
4	There is a challenge in getting adequately refrigerated vehicles to transport cold chain reagents					
5	There is no established distribution system for COVID-19 PCR reagents for all levels					

6. What are the main challenges you have experienced related to transporting and distribution of COVID-19 PCR reagents? ____

____

____

Part II. Logistics management information system

Level of agreement 1= strongly disagree 2=disagree 3= neutral 4= agree 5= strongly agree						
Ser. No	Items	1	2	3	4	5

1	There is a challenge in the availability of forms used to keep track of reagents in stock					
2	There is a delay in receiving reagents after being ordered					
3	The logistics management information system is not integrated with the laboratory management information system					
4	Summaries of consumption data are available					
5	Warehouse activities are not automated					
6	The logistics management information system report does not include Stock on hand					
7	The logistics management information system report does not include quantities used					
8	The logistics management information system report does not include losses and adjustments					
9	The logistics management information system is not automated					
10	There is a delay in sending reports to the higher level					

11. What are the main challenges you faced in Logistics management information system COVID-19 reagents? ____

____

____

Part III. Storage and handling

Level of agreement 1= strongly disagree 2=disagree 3= neutral 4= agree 5= strongly agree						
Ser. No	Items	1	2	3	4	5
1	Reagents are stored together with flammables and corrosives.					
2	There is no separation of damaged and/or expired reagents from usable products					
3	There is a standard guideline for the storage and handling of COVID-19 PCR reagents					
4	Fire safety equipment is not available and accessible					

5	There is consistent power supply and backup generator					
6	Products are protected from direct sunlight at all times of the day					
7	Roof is always maintained in good condition to avoid sunlight and water penetration.					
8	The current space and organization is sufficient for existing reagents and reasonable expansion					
9	There is a problem of cold storage capacity to handle the desired quantity of cold chain reagents					
10	There is frozen storage for reagents which require frozen condition					
11	Refrigerator is cleaned and deforested when it needs					
12	There is thermometer for controlling cold chain temperature					
13	There is thermometer for controlling room temperature					
14	Temperature chart is up-to-date					
15	Refrigerator temperature is recorded daily					
16	Freezer temperature is recorded daily					
17	Products are stored and organized in a manner accessible for first-to-expire, first-out (FEFO) counting and general management.					
18	There is adequate training for store man on the storage characteristics of COVID-19 PCR reagents					

19. What are the main challenges you faced in storage and handling of COVID-19 PCR reagents? ____

____

____

____

Part IV. Inventory management

Level of agreement 1= strongly disagree 2=disagree 3= neutral 4= agree 5= strongly agree						
S. No	Items	1	2	3	4	5

1	Experience emergency orders of COVID-19 PCR reagents					
2	There is occurrence of stock out of COVID-19 PCR reagents					
3	There is occurrence of over stock of COVID-19 PCR reagents					
4	There is occurrence of expiry of COVID-19 PCR reagents					
5	There are written provisions for the redistribution of over stocked reagents					
6	There is a policy of storing and issuing stock according to FEFO inventory control procedure					
7	Damaged and expired reagents are removed from stock records at all levels					
8	The laboratory has a set of minimum and maximum stock level for COVID-19 PCR reagents					
9	Stock level of COVID-19 PCR reagents is reviewed periodically					
10	Resupply quantities are determined by non-laboratory professionals					
11	The is disproportioning of reagents during distribution					

12. List COVID-19 PCR reagents you stock out of most frequently.

    ____

13. List theCOVID-19 RT-PCR reagents you have a surplus of most frequently.

    ____

14. What are the main challenges you faced in inventory management of COVID-19 PCR reagents?____

    ____

    ____

Part V. Human resource management

Level of agreement 1= strongly disagree 2=disagree 3= neutral 4= agree 5= strongly agree						
Ser. No	Items	1	2	3	4	5
1	There is shortage of trained professionals working on supply chain management.					
2	No adequate training is given on the logistics of COVID-19 PCR reagents for those working on logistics.					
3	No adequate training is given on the logistics of COVID-19 PCR reagents for those working on COVID-19 testing.					
4	Incentive is not given for those working on COVID-19					
5	There is turnover of professionals working on COVID-19 PCR testing					
6	There is turnover of professionals working on COVID-19 PCR reagents supply chain management					
7	There is no adequate supervision by higher organization on COVID-19 testing					

8. What are the main challenges you faced in human resource management?

____

____

____

Part VI. Public-private partnership

	Level of agreement 1= strongly disagree 2=disagree 3= neutral 4= agree 5= strongly agree					
Ser. No	Items	1	2	3	4	5
1	There is no sharing of COVID-19 PCR reagents between public and private health facilities with regard to this facility					
2	There is no policy prepared for Public-private partnership in this facility					
3	There is no agreement signed between public and private facilities					

	in this facility					
4	There is no tool used for integrating COVID-19 PCR testing reagent logistics between private and public facilities					
5	There is no collaboration between public and private in training professionals on COVID-19 testing and its logistics					
6	There is no established referral system between public and private facilities on COVID-19 testing in this facility					

7. What are the main challenges in public-private partnership**?**

____

____

Part VII. Delivery of testing service

Ser. No	Items	Never	Rarely	Sometimes	Often	always
1	Experience service interruption of covid-19 testing					
2	Experience delay in COVID-19 testing					
3	Experience backlog of untested samples					
4	Experience referral of samples to other COVID-19 testing sites					
	Short Answer Questions					
5	Average testing capacity of your laboratory in tests per day	____________				
6	Average turnaround time of COVID-19 PCR test in your laboratory in hours?	____________				
7	Maximum turnaround time of COVID-19 PCR test in your laboratory in hours when there is a delay?	____________				
8	What was the maximum duration of service interruption for COVID-19 testing in days?	____________				
9	What was the minimum duration of service interruption for COVID-19 testing in days?	____________				

Part VIII. General question

I. If there is any challenge you faced in the supply chain management of COVID-19 PCR testing not included in the above questions list it below.