Master's degree thesis

LOG950 Logistics

Improving visibility along the pharmaceutical supply chain: A case study on public health commodities supply system of Ethiopia.

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Molde University College
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Preface

This thesis is submitted in partial fulfillment of the requirements for the MSc. degree in logistics at Molde University College, specialized university in logistics, Molde, Norway.

This work has been carried out in the period between January and June 2016 with Associate Professor Jæger Bjørn, Molde University College, as supervisor. The thesis has three parts where part-I measures supply chain performance-, part-II analyzes the status of supply chain visibility- and part-III recommends approaches to enhance visibility -within the public health commodities supply system of Ethiopia.

The thesis consists of introductory, theoretical and methodological chapters, followed by three analysis chapters that represent the core of the thesis.

Acknowledgements

First and foremost, I am deeply grateful to my supervisor, Professor Jæger Bjørn. I am certain that I would have not made it so far if he had not believed in and motivated me. He stretched beyond boundaries to curb many 'Nos'. His continuous guidance, encouragement, interest, patience, knowledge and experience were my motivation and morale throughout this project. It would be my great wish to continue having his kind and sincere helping hands in my future career too and that would definitely would make me lucky.

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If I have to individually mention those helping hands; PFSA director general Mr.Meskele Lera and operation director Mr.Yemanebirhan Tadesse should have my big acknowledgment for letting me have the first broad and intuitive discussion from their very busy time and allowing the rest of the staff to work with me.

I am very grateful to Mr.Yared Yigezu, PFSA FCB directorate director who was a big asset to this project in helping me at every aspect I requested.

I am quite certain that this research project would have been a very difficult job, if I hadn't met Mr.Abebe Kassahun on my way, PFSA FCB directorate director office coordinator. A very humble, helping, resilient, optimist and wonderful guy who has never been tired of facilitating and assisting. I am very grateful for all his efforts.

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and wide data about the hospital working system. I am also very grateful to regional PFSA hub distribution pharmacists; Mr.Fitsum Girma, Mr.Tadele Awoke, Mr.Silene Abera, Mr.Faris Yasin , Mr.Endalew Asmamaw, Mr.Alebachew Ambello, who took their time to fill a survey questionnaire and Mr.Ammanuel Zinare, Mr.Sigewkal Awaze, Mr.Getachew Asfaw -medical representatives for pharmaceutical companies and hospital pharmacists who helped me in the data collection.

I am thankful to the unreplaceable and constant love and support my mom, brothers, sister, relatives and all those around who knows me shown while conducting this project. Mr.Micky Mulugeta and my all-time favorite-Antu, who became a reason to study my master's degree deserves my gratitude. My longtime friends Mr.Yordanos Zewdu, Mr. Behailu Kebede and Mr.Memhiru Melkamu were always on my side motivating me to not give up. They really are large part of this success. My special blessing also goes to my wife, Nardos Simeneh, who faithfully kept loving and appreciating me through all the challenges.

All those organizations who at the time wanted to help but were unable (due to budget deficiency) to fund this project and were very kind in their reply's: Dr.Nigusu Mekonnen from USAID, Mrs,Waranoot Tungittiplakorn from Utviklingsfondet, Professor. Kari Helene from Oslo university deserve my gratitude.

If it had not been by the grace, mercy, will and help of the mighty God, I would have not been able to do it by my power and wisdom. The special package of my gratitude goes to Jesus Christ, the Alpha and Omega, who kept me helping from the beginning to the end. *'Not that we are sufficient of ourselves to think anything as of ourselves, but our sufficiency is of God' 2 Corinthians 3:5-7*

Summary

Personal work experience within the health commodities supply system of Ethiopia which is challenged by poor inventory management, inefficient tracking and tracing, fake or sub-standard medicines and bullwhip effect, and a later combination of those experiences with an academic study at Molde University College became my motivation to conduct this research study. Focusing on one of the supply chain actors; to find out where the challenges outlined above, to look at supply chain visibility and to explore approaches, I formulated research questions. Supply chain performance indicators, a quantitative model with case study and a case study with a supply chain visibility scorecard are applied to answer research questions 1, 2 and 3 respectively.

What is the supply chain performance of the Ethiopian Public Health Commodities Supply System (EPHCSS)?

For the sampled products, actors and within the measuring period, vital products availability ranges from 65% to 84.4%, against a 100% service level agreement. 75% of the commodities experienced stock-out for 1 to 4 times within the past 6 months of time for a duration of 10 to 147 days. Only 16-50% of the products were stocked correctly where understocking being very likely. Forecast accuracy ranges from 0.22 to 2.59.

Supplier fill rate is 100% in quantity and lead time is 1 month for two of the products. There is no computer to computer ordering system between actors and stock status monitoring is conducted monthly by all sampled hubs.

How is Supply chain visibility implemented in the Ethiopian Public Health Commodities Supply System (EPHCSS)?

In the inbound section, there is a better partial visibility (2.99/4) with regard to foreign suppliers of program pharmaceuticals than with the local suppliers (2.91) and international suppliers (2.79/4) of RDF pharmaceutical. In the outbound section, information flows in the program supply line have a better accessibility (above 75%) but with moderate quality; accuracy (2.44/4) and freshness (1.56/4) than the RDF supply line; accessibility (3.13/4), accuracy (2.21/4) and freshness (1.18/4).

What are those approaches through which the supply chain visibility could be improved under the constraints of the EPHCSS?

GS1 data matrix barcoding with a unique serialization integrated with an inventory dashboard is one cost efficient approach recommended for the study system which would enable to easily track and trace products movement and offer data visibility as fresh and accurate as possible. Accurate, fresh and data rich inventory dashboard would enable decision makers to have a proactive approach therefore would trigger a better stock management. A unique serialization of products and an authorization at the time of receive and issue would block most possible ways of counterfeited and unauthorized medicines inflow.

The responsible management body should take this urgent issue of product availability and low value of indicators to consideration for further wide analysis or appropriate measures. Diagnostic measures on the quality of data visibility should be taken. Further studies with adequate data to find out practices and experiences of program supply line over RDF supply line is advisable. In addition, to have a more detailed insight about the impacts of the recommended visibility approaches: it is recommendable to conduct a pilot project study.

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Abbreviations

EPHCSS – Ethiopian Public Health Commodities Supply System

SCV – Supply Chain Visibility

PFSA – Pharmaceutical Fund and Supply Agency

GS1 –Global Standard 1

HCMIS –Health Commodity Management Information System

IPLS-Integrated Pharmaceutical Logistics System

RRF- Report and Requisition Format

IFRR – Internal Facility Reporting and Requisition

USAID – United States Agency for International Development

APTS – Auditable Pharmaceuticals Transactions and Services

RFID – Radio Frequency Identification

ERP – Enterprise Resource Planning

ART – Anti-retroviral Therapy

WHO – World Health Organization

FMOH-Federal Ministry of Health

HSDP – Health Sector Development Plan

HSTP – Health Sector Transformation Plan

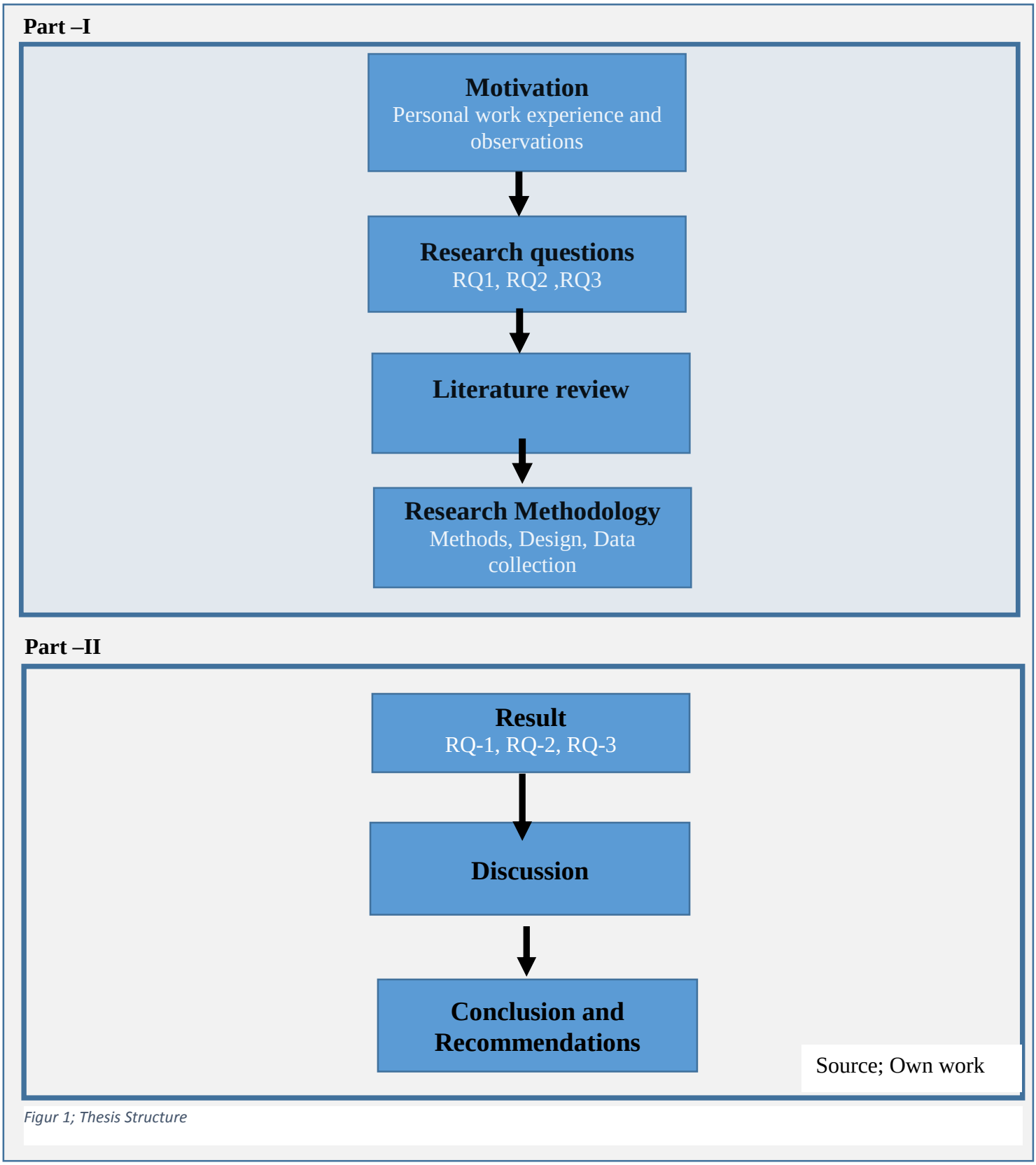
SOP – Standard Operating Procedures

FCB – Forecasting and Capacity Building

SDO – Storage and Distribution Office

RDF – Revolving Drug Fund

1.4. Thesis Structure



Figur 1; Thesis Structure

1.0 Introduction

1.1 Motivation

The advantage of having three years of personal working experience in the health care system of Ethiopia as a supply chain pharmacist and department head in a governmental pharmaceutical importer and wholesaler, PFSA, became a motivation for me to undergo this study. My position was in one of the 11 regional hubs studied in this thesis. The duty of the job was to manage the storage and distribution of pharmaceuticals that should pass through the hub to serve all health institutions within the hub's radius which was in the southwestern region of Ethiopia.

Through all this experiences, I have observed and became very familiar with common challenges that were frequent within the supply chain;

- High and frequent Stock-out rate, leading to
  Shortage of (vital) health commodities, therapy discontinuation, death risk, good opportunity to drug resistance especially for the most dangerous cases in Tuberculosis and poor health service
- Overstock inventory (mostly with a shorter shelf life and near expiry dates), leading to
  High rate of expiry, a risk to becoming expired and financial loss for an extra holding cost
- Counterfeited commodities within the legitimate line, leading to
  Loss of lives, economic impact and loss of trust on the public health
- Hectic and manually laborious commodity tracing system during a product recall leading to
  Inefficient tracking and tracing of all the required items belonging to the batch recalled and a non-speedy system allowing some of those items to already be used

Figuring out and being involved in those challenges was my head ache and triggered my alertness to find out where truly the challenges are, and further to explore approaches to intervene the challenges.

Since the time I joined the academic study in Molde University College, the studies I took and indications/ suggestions from professors gave me the insight and became a real motivation for me to take this topic as my MSc research.

1.2 Research Questions

To find out where the challenges outlined above, I formulated research question 1 as:

- *What is the supply chain performance of the Ethiopian Public Health Commodities Supply System (EPHCSS)?*

In the three-tier supply chain, one of the key players and central body in the EPHCSS is the pharmaceuticals fund and supply agency (PFSA) which has the responsibility of quantification, procurement, inventory management and distribution of pharmaceuticals within Ethiopia. It is the focal company within EPHCSS.

There are so far very few scientific studies conducted which focused specifically on PFSA supply chain challenges mentioned above. The ones that exists are informal and non-recent. Therefore, studying the supply chain performance of the focal company by applying key supply chain performance indicators, will give a scientific perspective about the significance of the challenges and an indication about the activities or processes to target in an intervention.

The supply chain performance indicators used to answer research question 1 are indicators measuring operational performance, e.g. like stock-out rate and order fulfillment rate. The operational performance in turn depends on a range of environmental and infrastructure factors like business environment, governmental regulations and technological infrastructure. The current situation for Ethiopia regarding such broad factors is briefly described in the thesis.

As a key motivation is to explore approaches to improve supply chain performance, I have looked for measures that can tell where to put the focus.
Supply chain visibility is rated as the most important measure for supply chain performance both by business leaders and researchers, (McIntire 2014).Therefore I decided to look at supply chain visibility in particular by formulating research question 2.

- *How is Supply Chain Visibility implemented in EPHCSS?*

Efficient supply chain visibility is one of the priority qualities required to have in a supply chain to counteract bullwhip effect, inefficient tracing and tracking and counterfeit medicines. There had not been any supply chain visibility studies so far conducted in the study system. Being able to know the

current inbound and outbound supply chain visibility status of the focal system is therefore a key element to base future benchmarking and undergo diagnostic measures more easily in the areas where a visibility improvement is more urgent.

Lastly, to explore approaches to improve supply chain performance, I focus on supply chain visibility aspects. Research question 3 is:

- *What are those approaches through which the supply chain visibility could be improved under the constraints of the EPHCSS?*

There are different kind of solutions and approaches in use to enhancing supply chain visibility. Having the fact that, supply chain visibility boosts the power of a company in fighting the supply chain challenges, research question three, analyzes points and possibilities of improvement within EPHCSS, and recommends approaches, which could enhance the visibility and thereby the supply chain performance.

1.3 Literature reviews

Supply chain performance

There are several studies done about the health commodities supply chain performance of the EPHCSS where most of the studies focused only on health facilities, one integral part of the health system(Berhanemeskel 2014, Shewarega et al. 2015, Sinishaw et al. 2015, Tessema and Amene 2012, Biruk et al. 2014). Even if the performance study on health facilities has an implication about the whole system, there are so far very few and limited scientific supply chain performance studies focusing on PFSA.

Two recent studies made to assess the health commodities supply chain management in selected public health institutions in Ethiopia shows: Lack of adequate supply of products, frequent stock-outs, frequent emergency order of drugs, understocking, significant variation in availability of key medicines and poor supply performance of importers, (MoH 2015 , Berhanemeskel 2014).

An Ethiopian national survey indicates poor order fill rate (the percentage of items that are filled, based on the ordered quantities with the correct products) to health institutions, shortages of products at central level, and product overstocking , (Shewarega et al. 2015).

A research study to assess the distribution and availability of essential tuberculosis diagnostic items in eighty health institutions in Ethiopia show ineffective distribution due to complete stock out of products which challenged sustainable supply of tuberculosis laboratory reagents ,associated with weak tuberculosis diagnostic and follow up services which latter triggered reluctance of health personnel at all levels not to make ordinary product requests, (Sinishaw et al. 2015).

An Ethiopian situational assessment shows significant challenges within PFSA in record-keeping, forecasted data quality, timely requisition and consumption reporting. Wastage of pharmaceuticals due to expiry, theft, and damage were found. Huge gaps in recording and documentation of pharmaceuticals that are unfit for use at health facilities were also documented, (MoH 2015).

A comparative quality evaluation study for marketed medicines indicated the existence of counterfeit medicines within the legitimate supply chain,(Sahle et al. 2012). Another nationwide survey also gave a highlight of how prevalent substandard products are fed into the supply system of Ethiopia, (Suleman et al. 2014). This survey which assessed the quality of medicines evidenced the high prevalence of poor quality drugs within the supply chain. The clear limitations in safety and quality assessment for medicines prior to their entry to market and poor post-marketing surveillance are another batch of logistic risks which resulted in loss of trust by the public as shown by national assessment study,(MoH 2015).

The reviewed literature studies clearly show that it is a high time for the Ethiopian health care supply chain to put into effect an intervention mechanism to the versatile challenges they are experiencing which is impeding the health care delivery and consequently the health of the population.

Supply chain visibility

Supply chain visibility studies are totally new to EPHCSS. I could not find any scientific studies conducted so far on the study group. However, International studies focusing on the different benefits of supply chain visibility, ways of measuring, and improvement approaches are multiple.

Supply chain visibility in a wide perspective is defined as the ability of a focal company and actors within a supply chain to access, share, capture, integrate, create intelligence of/from a key, useful or

important information or that information readily availability for monitoring, controlling, changing or decision making purposes, (Caridi et al. 2014, Barratt and Oke 2007, Francis 2008., McIntire 2014 , Musa, Gunasekaran, and Yusuf 2014).

Several researches and case studies indicate that supply chain visibility improve company performance: by supporting the decision-making process. Supply chain visibility increases information availability and accuracy therefore making the supply chain responsive, reliable and flexible. One way or the other, the common supply challenges are a direct result of poor visibility or decision making made on inaccurate/out-of-date data, (Caridi et al. 2014, Barratt and Oke 2007, Musa, Gunasekaran, and Yusuf 2014, Schoenthaler 2003, Wang, G., and Wei 2007).

Supply chain visibility increases demand visibility between members of the supply chain. How well demand forecasts can be improved depends on how visible the underlying demand actually is. Demand visibility here refers to the ability to see undistorted and accurate demand within the timeframe necessary to react to it, (Schrieber and Jared 2005). The more visible the demand, the greater the likelihood of accurate demand forecasts. Most retailers do not know their demand with certainty, they make their inventory decisions based on demand forecasts. When the forecast is not very accurate, the quantity they order does not reflect the demand for the periods that the ordered quantity is supposed to cover. The errors in the retailer's forecasts are passed to the supplier in the form of distorted orders: bullwhip effect. By appropriately sharing accurate information between suppliers and retailers and coordinating replenishment and production decisions under demand uncertainty, suppliers are able to smooth the peaks and the valleys in the flow of goods : to reduce the bullwhip effect. Studies show that solutions like vendor managed inventory (VMI) which enhance visibility reduce bullwhip effect by 50 %,(Marqués et al. 2010.).

Cost optimization (production, logistics and transportation costs), effective distribution of inventory, efficient service levels, product availability, accurate demand forecasting, efficient tracking and tracing, product authentication are few of the main benefits of a successful supply chain visibility, (Zhao et al. 2002, Yao, Yuliang, and Dresner 2008, Ryu, Tsukishima, and Onari 2009).

Therefore, for any supply chain system which aspires to improve its handling of supply chain challenges associated with poor inventory management, tracking and tracing inefficiencies and entry of fake products, have enhancing the supply chain visibility as a prime objective.

There are so far no supply chain visibility studies conducted on EPHCSS to benchmark and baseline a recommendation solution. This study will show how supply chain visibility is currently implemented in EPHCSS. From the review of literatures, it can be seen that, visibility can be measured from different perspectives and assumptions. While measuring, supply chain visibility is considered to influence the supply chain operation, which in turn influence the business outcomes, (McIntire 2014 , Caridi et al. 2010a).

1.4 Country context and study system

Ethiopia, located in the North East part of Africa is the oldest independent and second most populous (96 million) country in Africa. It served as a symbol of African independence throughout the colonial period, and was a founding member of the United Nations and the African base for many international organizations, (Bank 2016 , Wikipedia 2016).

As of 2015, there are a cumulative number of 311 hospitals (including private), 3,547 health centers and 16,440 health posts available. About half of health facilities have regular electricity or has functional generator with fuel. About 88-100% of hospitals (public & private), 57% health centers and 29% of health posts have regular power sources. Information communication technology development in the health sector focused on tele-education, tele-medicine, electronic health management information system (eHMIS) and electronic medical records (EMR). Health technology management, including medical equipment maintenance, are among areas that are in focus by the national health sector development plan (HSDP) of Ethiopia, (MoH 2015).

FMHACA (Food, Medicine and Health Care Administration and Control Authority), a sub-ordinate of the Ministry of Health, is the authority given the mandate of food and pharmaceuticals regulation. FMHACA owns the national quality control laboratory, which is equipped with different testing and analyzing devices to undergo physicochemical tests. It also updates each year the list of national medicines, (FMHACA 2013).

The Ethiopian Public Health Commodities Supply System (EPHCSS)

The Pharmaceutical Supply Chain (PSC) is ''the integration of all activities associated with the flow and transformation of drugs from raw materials through to the end user, as well as associated information flows, through improved supply chain relationships to achieve a sustainable competitive advantage''(Uthayakumar and Priyan 2013)

The pharmaceutical supply chain is unique compared to other supply chains. First, anything less than a customer service level of 100% is unacceptable because of the direct impact on health and safety. Ensuring a 100% product availability at a feasible cost represents a huge challenge requiring the supply chain processes to be streamlined towards customer demands. Second, product perishability is another critical issue. Outdated or expired items may be overlooked and dispensed to patients, which could have potentially disastrous effects on both patient care and public relations. Third, complexity of the network system and strict regulations is quite big. Fourth, the pharmaceuticals require special storage and transportation conditions like cold room storage system(2-8^{o}c), deep freeze storage system (< 0^{o}c) and sun-light protected storage area, (Whewell 2012).

The Ethiopian public health commodities supply system (EPHCSS) mainly comprises of three major players: producers, purchasers, and pharmaceutical providers. The EPHCSS constitutes; Manufacturers/Importers, Wholesalers(National/Regional), and health facilities as core actors (PFSA,2015).

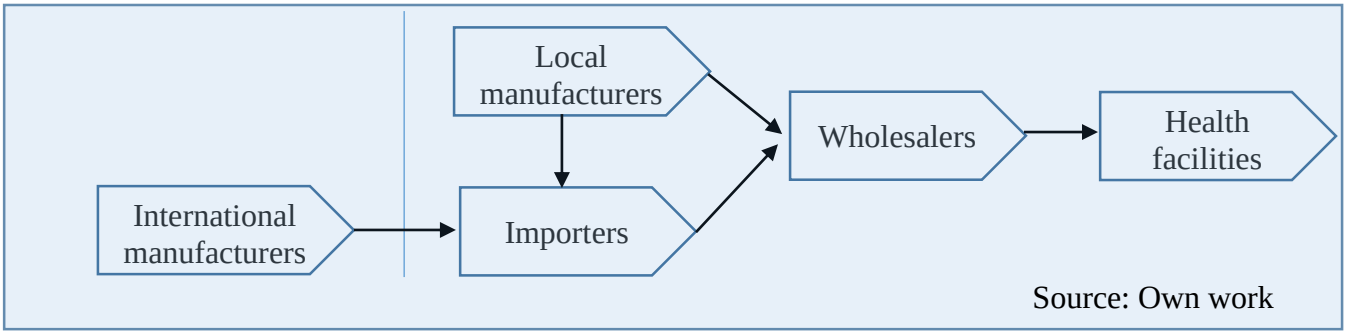


Figure 2; Main Skeleton of the EHCSS supply chain

There are 257 private importers /wholesalers and 1 public importer/wholesaler (with 11 regional hubs) as of 2014 all over the country, (FMHACA 2014).

As of 2010, the country's national drug list has 1189 pharmaceutical product groups, which can be imported or locally produced subject to compliance with the registration requirements of the authority. 877 suppliers (both local and international) supply those product groups; 854 of the products are anti-retroviral therapy class products and agents, 8 anti-malarial product class and 327 are other class. Local manufacturers covers 20% demand of the country's pharmaceutical need, (FMHACA 2013 , MoH 2015).

The government of Ethiopia has established an agency named PFSA - the Pharmaceuticals Fund and Supply Agency- an autonomous federal organ having its own legal personality with the purpose of guaranteeing a continuous supply of quality assured essential medicines, at an affordable price to public health facilities, (PFSA 2014).

PFSA – (Pharmaceuticals Fund and Supply Agency), (PFSA 2015, MoH 2015 , PFSA 2014)
PFSA is the focal company of focus in this study, which is a sole government organization handling distribution of health commodities to the public health institutions. It handles forecasting, procurement, storage, distribution and rational use of drugs. Securing 100 percent availability and continuous supply of vital health commodities is the primary goal of the service level agreement (SLA) of the agency. It procures pharmaceuticals from local and international manufacturers, stores in its central hub and distributes it to 11 hubs (red dots on the map) and 7 sub-hubs (blue dots) dispersed geographically proximal to health facilities. Moreover, from the regional hubs goes down to health facilities where the end customer gets the commodities.

Source:(PFSA,2015)

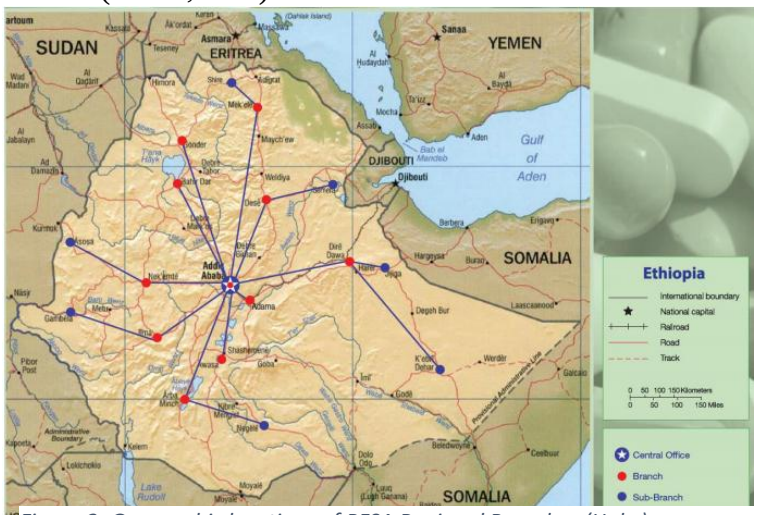


Figure 3; Geographic locations of PFSA Regional Branches (Hubs)

The Agency's annual distribution capacity has increased from 2.74 Billion ETB[1] in 2011 to 12.10 Billion ETB in 2015. Seventeen modern warehouses are completed which raised the national storage capacity from 46,260 m3 to 531,000 m3 and the cold chain storage capacity from 50 m3 to 800 m3. PFSA has seven directorate departments (figure 6) with unique job responsibilities: Forecasting and Capacity building, Storage and distribution, Fund management, Pharmaceuticals and Medical Supplies Procurement, Human Resource & General Service and Planning/MIS and Public relations office.

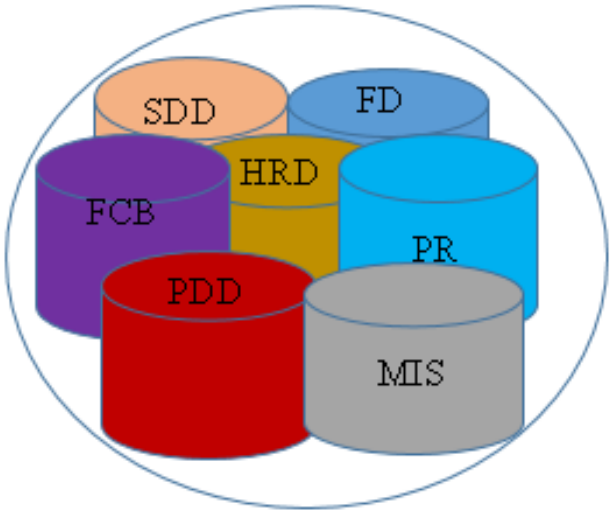


Figure 4; Organizational department setup of PFSA

Source: Own work

As an agency with a prime responsibility of managing the pharmaceutical logistics system of the country, PFSA has indispensable roles and responsibilities (Annex 6.4).

The health commodities, which PFSA is providing to the public health institutions, are majorly of two categories: Free (Program) and Purchase (RDF-Revolving Drug Fund).

The Program group constitutes; drugs, reagents and medical supplies related to ART (Anti-Retroviral Therapy), TB/Leprosy, Family Planning, Malaria, and Infection Prevention. The government, global donors and other stakeholders are key players within the supply chain of program pharmaceuticals in donating to the purchase of the items, infrastructure and capacity building.

[1] 1 ETB = 0.046 USD (http://www.xe.com/currencyconverter/convert/?Amount=1&From=USD&To=ETB)

The RDF group constitutes; drugs, reagents and medical supplies related to any vital, essential and non-essential list of items. They are not specifically bought for a given treatment groups, but for a general use based on the national drug list as per the need of facilities They are served with a 20% or 30% of marginal profit to the public and the profit is revolved to purchase another quantified and forecasted need of items in a new budget year.

The supply and distribution of pharmaceuticals are done using an integrated information system; Integrated Pharmaceutical Logistic System (IPLS)(Annex 6.5).

2.0 Research Methodology, research design, data collection

2.1 Research methodology

2.1.1 Research question 1 methodologies;

2.1.1.1 Methodology one;

To measure the supply chain performance of the system, specifically of the focal company, six key supply chain performance indicators, which have a link with the research challenges are selected from a guide prepared by USAid, (Aronovich et al. May 2010).

Though the guide enables to measure up to a total of seventy (70) indicators segregated in function and four indicators (Annex 6.6), but for the following key reasons seven were selected to be used for this research study.

1) Theme and purpose of the research study; the findings of those selected indicators shall indicate the significance and weight of the research problems and could be taken as an input while making recommendation to the other part of this study. Therefore, only those indicators which are believed to have a link with the research problems, visibility and the theme of this research topic are selected.

2) Limited time for data collection; especially from a system where many procedures are done manually and where paper data tracking may become a mandatory part of the job, getting data for all the 70 indicators would require and consume a great amount of time beyond what is scheduled and allocated in the time table for this research study.

Therefore, for this research project; a total of eight (7) indicators with 3 indicators of quality (from the inventory management and product forecasting function group), 1 indicator of response time (from the inventory management function) and 3 indicators of productivity (from the inventory management, sourcing and procurement function) were selected.

Table 1; Supply chain performance indicators along with the logistics functions they target

Supply chain/logistics functions	Indicators		
	Quality	**Response time**	**Productivity**
Inventory management/LMIS/ customer response	1. Stock out rate 2. Plan in place for predictable change in demand	3. Order Lead time	4. Percentage of orders placed through electronic ordering system
Supplier/Sourcing (from purchasers perspective)			5. Supplier Fill rate
Product selection/Forecasting/Procurement	6. Forecast accuracy error		7. % of purchase orders /contracts issued as emergency orders

Source : (Aronovich et al. May 2010)

2.1.1.2 Methodology two;

Two of the research problems are in and around the area of product availability. Therefore, a product availability survey for six (6) regional hubs is conducted for a basket of sixteen (16) vital pharmaceuticals; 11 RDF and 5 Program. As the product availability survey questionnaire table (Annex 7.9) has previously been used to conduct a national survey at health facilities level, there was no need of conducting a pilot study prior to using it.

2.1.2 Research question 2 methodology;

A quantitative model enabling to measure the visibility level in complex supply networks, from an inbound and outbound side with an ambition targeting on benchmarking and diagnostic purpose is applied, (Maria Caridi 2010).

Therefore while using the model, structured approaches were followed to assess the visibility of the focal company –PFSA-has of its supply chain. Doing that, instrumental steps were ensued to reach the final goal (Annex 6.6).

2.1.3 Research question 3 methodologies:

2.1.3.1 Methodology one;

To get a deep insight of the system, especially the whole process and activities in and around the focal company, a case study methodology is followed. The case is studied with an intrinsic interest focusing on understanding the EPHCSS, mainly the work flow of the focal company. Triangulation provided an important way of ensuring the validity of the data; previous work experience, standard operating procedures and interviews.

2.1.3.2 Methodology two:

A qualitative and quantitative approach/score-carding technique is used to assess effectiveness of the recommended improvement approaches. The approach has its own metrics and methodology referred to as the "supply chain visibility scorecard", and it represent an approach to measuring the performance of supply chain visibility directly without conflating the metrics with the impact visibility is having on the overall supply chain operation. The scorecard is decomposed in to four primary metrics which directly reflect on the performance of the four steps within supply chain visibility (Annex 8.0), (McIntire 2014).

2.2 Research design

2.2.1 Research question 1 design

2.2.1.1 Method 1;

Values for the formula variables are grabbed for three product lines; 1 pharmaceutical product from each; RDF, Program International suppliers and RDF local suppliers.

List of variables where their values (recent data) gathered;

- Forecasted consumption
- Actual consumption
- Total number of orders placed for the product
- Number of emergency orders made on the product
- Total quantity ordered (for the product)
- Number of order lines/SKUs/ shipped in initial shipment (for the product)
- Total number of hubs that are expected to offer that product
- Number of hubs that experienced a stock-out of a specific product

- List of plans in place to respond to seasonal variance in demand
- Total number of orders placed
- Sum of the number of days between when orders were placed and when orders were received
- Number of orders placed through electronic system

2.2.1.2 Method 2;

For the list of products identified as fast-moving, vital and high consumption, a product availability survey table constituting data input columns were filled by six PFSA regional hub pharmacists working in the supply chain unit.

2.2.2 Research question 2 design;

To make the study specific, suppliers of vital, high-consumption and fast moving products from the context of the country, are part of this study.

The kind of information flows that exchanged within the selected pharmaceutical suppliers and hospitals is collected and categorized into the four types of information flows. Local suppliers, international suppliers of program pharmaceuticals and international suppliers of RDF pharmaceuticals are the three key groups of suppliers. While Black Lion hospital, Alert hospital and Emmanuel hospital are the three key health institutions.

How much (quantity) of the information flows exchanged within pharmaceutical suppliers and health institutions does the focal company accesses and of in what quality (accuracy and freshness) is quantified and graded in scale of 1-4 based on the ranking system offered by the methodology(Annex 8.0).

2.2.3 Research question 3 design;

First, reasons for insufficient supply chain visibility are identified leading to possible areas for improvement. Second, a time series analysis of chronological sequence is done. Third, based on the insights from the case study, a process model is designed coherent of the individual supply chain process steps and actors of the system. Fourth, based on the process model, unused potentials of visibility were identified. Fifth, in addition, to that, key points which are certainly critical for the creation of the research problems are identified. Sixth, based on the insight of the case study, references of similar projects, cases from the literature and my advisors personal expertise; improvement

recommendations were suggested. Seventh, and finally, those improvement recommendations were analyzed for a fitness of relevance.

2.3 Data collection

The time period of the data collection with the kind of activity held is summarized in table two. Generally; interviews, focus group discussions, email surveys, questionnaires, firm entity visits, data analysis were key data gathering methods used.

Table 2; Data collection: type of collection method, theme and time frame

	Type	Theme (Activity)	Time period
RSQ1	1. Discussion and interviews with PFSA FCB unit (Appointment in person)	Key 1; To collect the variables for the index; the seven supply chain performance metrics	February 4- March 1
	2. Data Analysis (Records, archives, SOP's)		
	1. Survey tables spread to 11 main regional hubs through an email communication (> 3 times), and six replied during the time frame of the data collection	Key 2; Product availability table to assess stock-outs and overstock,	March 20
RSQ2	1. Discussions and interviews(based on semi-structured questionnaires) with local pharmaceutical manufacturing company representatives; *Julphar, Cadilla, APF, Epharm*	Key 3; Needed for the approach- to build the **product process flow** within pharmaceutical suppliers Key 4; From that to find out what **information the international suppliers exchange** on those products they supply to PFSA	February 4- March 1
	2. Email communications and website material access for international suppliers: *Auro bindo Pharma Limited, Macleods ,San ,Strides , Arcolab , GlaxoSmithKline (GSK), Egyptian International EIPICO, Gulf Pharmaceuticals, Huanggang Hyangzhou, Truskin Glove Pvt.Ltd, Vins Biopoducts Ltd, CSPC Zhongnuo Pharmaceutical*		
	1. Discussion and interview with PFSA general director		

	2. Discussion and interviews with selected hospital pharmacy heads (BLH, Emmanuel, Alert hospital - appointment in person)	Key 5; Needed for the approach- to build the **product process flow** and **activity flows** within health institutions Key 6; From that to find out what **information the institutions exchange** on those products they are supplied by PFSA	
	1. Discussion and semi-structured interviews with PFSA FCB unit (Directorate director, coordinator, officers- appointment in person)	Key 7; Needed for the approach – to mark **how** and **what** or **which** of the information the international suppliers/health institutions exchange does this core company access/share	
	1. Data Analysis of financial documents(yearly purchase amounts, hub consumption reports)	Key 8; Needed for the approach- to select and grade those pharmaceuticals focused for this research and to grade the suppliers significance with respect to the hub	
RSQ3	1. Focus group discussions with FCB and SD team, 2. Rigorous interviews, 3. Site visit 4. Data analysis from department SOP's, analysis of case studies and literature reviews	Key 9; To draw the process map of the core company and to study and recommend similar improvement approaches	February 4- March 1

Source: Own work

3.0 Data Analysis and discussion

3.1 Part I- Supply chain performance

3.1.1 Section-I-Supply chain performance indicators

The data collection is done based on three products; one product from the RDF/International suppliers (Chloramphenicol Sodium Succinate 1gm injection), one product from RDF/local suppliers (Amoxicillin 500mg capsule) and one product from program category (Lamivudine 300mg/Tenofovir 300mg/Efavirenz 600mg). Highest consumption and vital products are selected. Measurement procedures indicated by the guideline were followed (Annex 6.7) to come up with the following results.

Table 3; Summary of supply chain performance indicators

		Performance indicators						
Product group	Sample pharmaceuticals	Stock-out rates (%)	Order lead time(month)	Supplier fill rate(%)	Forecast accuracy error	Percentage of purchase orders/contracts issued as emergency orders	Plan in place for predictable change in demand	Percentage of orders placed through electronic ordering system
RDF/INT	CAF inj	36.3	> 1	100	2.59	0	***Monthly stock status monitoring is implemented in all hubs***	***None***
RDF/LOC	Amox 500	0	1	100[2]	0.25	0		
PROG/INT	3TC/TDF/EFV-adult	27.2	3	100	0.22	20%		

[2] Special Condition

Research question 1:

- *What is the supply chain performance of EPHCSS?*

As mentioned on the motivational part of this study, the studies so far available concerning the health care supply chain performance of Ethiopia targeted only two of the actors within the system; health facilities (hospitals, health centers and health posts) and suppliers. PFSA, which is the main role player in the public health supply chain of Ethiopia, has not been the main target of such similar studies so far .Facilities stock status , product availability and every other health commodities logistics issues and risks are directly dependent on the performance of PFSA. At the same time, every communication of suppliers with health facilities is through PFSA, strengthening the vitality of PFSA in the health care supply chain. Even-though the main target of this study is mainly visibility, recommendation of improvement approaches, but the paper also aims to give an insight about the supply chain performance of PFSA no matter the measurements, and sample used are limited. Limited measurements are better than no measurements/data, as they give at least some insight in the characteristics of EPHCSS.

Stock-out rate of the focal company ranged from 0% to 36.3%. The focal company experienced no stock out in its hubs during the whole year of 2015 for the locally supplied product, while three of the hubs experienced stock-out for the internationally supplied program product and four of the hubs for the internationally supplied RDF product. As a direct implication of this, 20% of the orders for the program drug were issued as an emergency order, while there were no emergency orders within the year for the locally supplied product. It may seem counterintuitive not finding any emergency orders made during the year for the internationally supplied RDF product. Forecast accuracy error as per MAPE (mean average percentage error) is 2.59, 0.25 and 0.22 for the internationally produced RDF, locally produced and internationally produced program products respectively. High amount forecasted but less amount consumed, but confusingly high stock-out rate of 36.3% and no emergency orders. Deep investigation on this result shows that, the distribution was poor making those hubs who had the product in an overstocked level which later was recognized so that a branch to branch transfer done avoiding the emergency ordering. Even if the data it is based is limited, but the sample scenario shows poor forecast efficiency and distribution rationing which probably created overstock inventory in some hubs and stock-outs in others.

All the three suppliers' capacity of supplying the exact amount and on the exact date specified on the contract was 100%, which takes away the burden of blaming the suppliers for stock problem by the focal company for three of the sample products for the measurement year. The average lead-time for the program supplier is 3 months. While 1 month for the local supplier and none of the orders have physically arrived for the selected product by the RDF international supplier.

For all the three products, orders from focal company to suppliers is fully non electronic ordering system referring to an electronic ordering system as an IT-system used while conducting a purchase or an order, for direct communication with the supplier's IT-system with no humans involved. Email, phone, fax, or other electronic communication means's are not official and primary use, rather a letter ordering system, which the focal company uses.

Likewise the focal company-supplier relationships, the health institutions main means of communication in product ordering is also in paper format called RRF (Report and requisition format) which has to be filled and sent through a mail or delivered in person.

The only plan available for managing a predictable change in demand by the focal company is a monthly stock-status monitoring scheme by the FCB department. All eleven hubs (which normally represent the focal company-PFSA) complete a report of "warehouse stock status in quantity" which is a reconciled data from HCMIS and paper bin-card, every month. Such a long time to assess stock-status of hubs (poor quality of internal visibility of stock-status) probably is one factor, which creates poor intervention towards overstock inventory, especially for products with near expiry dates.

3.1.2 Section-II, Product availability

The most important output of a logistics system is stock availability since it will improve health outcomes. Unavailability in any health system is considered a critical system failure since stock-outs can result in patients going without life-saving pharmaceuticals. An additional effect is the reduced confidence in the health system. Even where stock-outs are rare, hubs with too little stock at the time of the survey are either likely to stock-out or will require an emergency order before they receive their next routine order; while overstocks can mean waste and inefficiency,(Shewarega et al. 2015).

To assess stock availability at PFSA hubs, the questionnaire collected data on stock on hand, frequency and duration of stock-outs on the day of survey and during the six months prior to the survey for six (6) PFSA hubs.

Stock-out data this time is directly collected from the hubs for the instant time of the data collection period and for the six months of time prior to the data collection. However, at section-I, the annual report of the forecasting and capacity building department is reviewed. Therefore, this measure offers a more updated and accurate data.

3.1.2.1 Availability on day of visit (Annex 6.8)

Overall, the majority of the PFSA hubs had most of the essential pharmaceuticals in stock on the day of the data survey: average availability is 84.4 percent for the basket of commodities, for six regional PFSA hubs. Of the 16 items assessed, availability is 100 percent for 8 items, 83.3 percent for four items, 66.7 % for three items and 16.7 % for one item.

Products with 100 percent availability at regional hubs are (4 out of the 11 RDF products and 4 out of the 5 program products) Nifedipine, Erytromycin, Gauze Surgical, Amoxicillin, 3TC/TDF/EFZ, AZT/3TC/NVP, RHZE and Co-artem. Overall, availability of (3 RDF and 1 Program) CAF, Cimetidine inj, Cotrimoxazole suspension and Depo is good (83.3%). Ciprofloxacin, TAT and Insulin suspension (all three from the RDF category) availability is low at 66.7% and surgical glove (RDF product) being only available in one hub.

3.1.2.2 Availability within last six months (Annex 6.9)

Data is also collected on the availability of the selected products throughout the six-months prior to the assessment—how many times hubs had stocked out and for how many days. This information is useful in determining whether hubs chronically or intermittently stock-out. Data are collected by reviewing the HCMIS (Health Commodities Management Information System) and bin cards; not on a physical inventory. Bin-cards at PFSA are paper formats of stock control that are used to register, receive and issue of items with a current balancing record. HCMIS in the other hand is an electronical way of doing receive and issue records, (Annex 6.3). Therefore, for the selected products, the past progress history on the records is reviewed to find out the number of times and the duration of days

the record reading had been zero. Therefore, the accuracy of the indicator relies on the hubs recordkeeping.

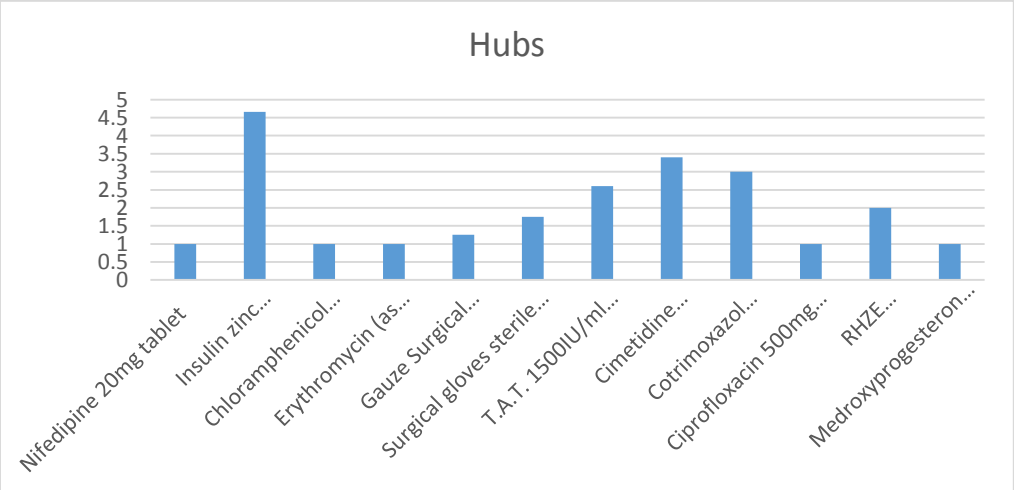
The average stock availability in the past 6 months is 66.67%. Availability of four products during the past six months is 100% (3 from the Program and 1 RDF locally supplied), 83.3% for four products, 66.67 % for three products, 50% for one product, 33.3% for one product and 16.67 % for three products. During the last six months, all the program products included in this study except depo-provera and RHZE are the most available products at the hubs—with a 100% of availability.

Stock-outs for gauze surgical, TAT, Cimetidine,(all three from the RDF category) are high compared to other products, with a stock-out of atleast once in four of the hubs in the six months prior to the survey.

3.1.2.3 Frequency of stock-outs

In hubs that had a stock-out of a product at least once in the six months prior to the survey, the survey assessed the number of times a stock-out occurred. The frequency of stock-out is from a range of once to four times average. Stock-outs of Insulin, Cimetidine and cotrimoxazole suspension (all RDF) is more frequent: they occurred, on average 4.6, 3.4 and 3 times, respectively. Frequency of stock-outs is lower for CAF, Erythromycin, Nifedipine, Ciprofloxacin, and Depo-Provera (three Program and one RDF).

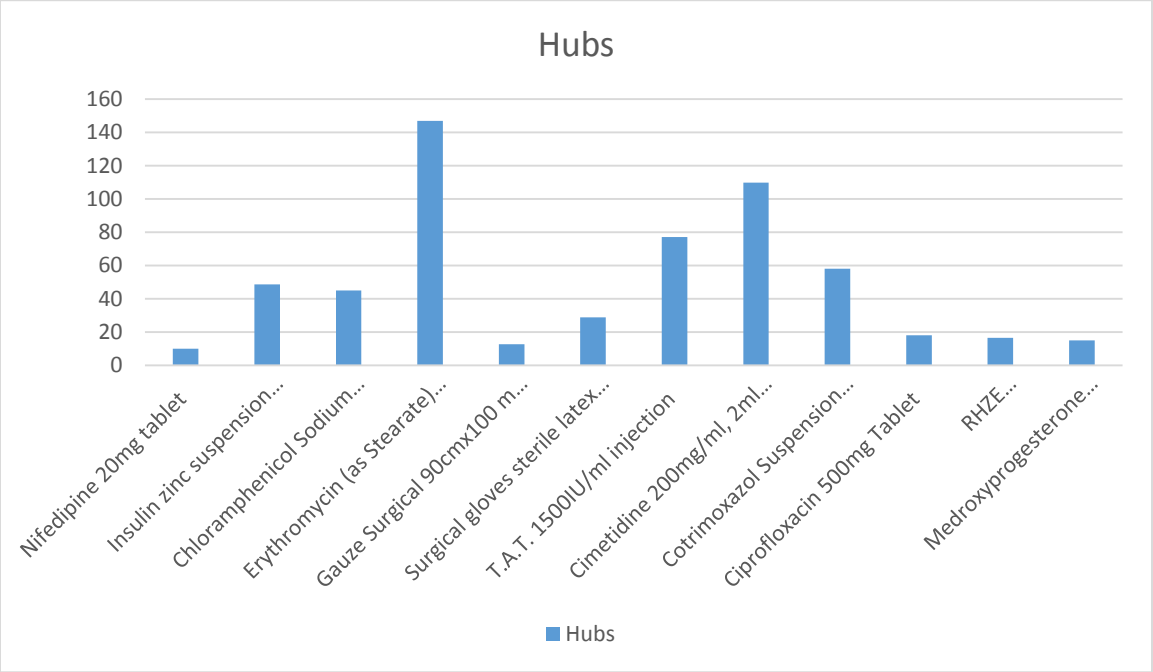
Figure 5; Frequency of stock-outs within the last six months prior to the survey by hub type, April 2016



3.1.2.4 Duration of stock-outs

The average duration of stock-outs varied widely among the products, ranging from 10 to 147 days. The duration for erythromycin, cimetidine, TAT, cotri-moxazole suspension and insulin (all from the RDF category) is the highest; being an average of 147, 109, 77, 58 and 48 days respectively. While stock-outs of RHZE and Depo-provera (the two products from program line) being 16.5 and 16 days respectively.

Figure 6; Duration of stock-outs within the last six months prior to the survey by hub type, April 2016



3.1.2.5 Stock on hand (months of stock)

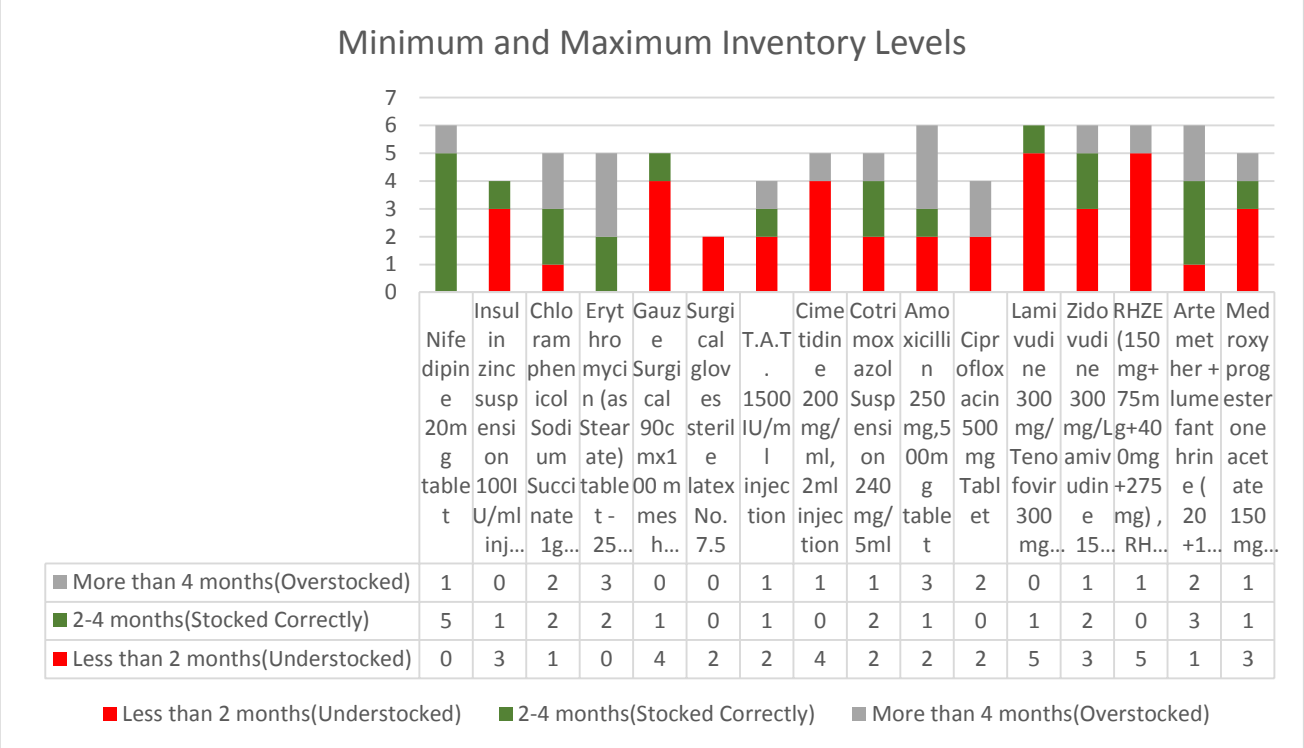
IPLS (Integrated Pharmaceutical Logistic System) introduced minimum and maximum inventory levels for the regional hubs. Regional hubs have a minimum inventory of two months of stock and a maximum of four months. Proper commodity management ensure that inventory levels remain within this set range, (PFSA 2015).

Using issues data to assess a hub's stock status, the average monthly consumption (AMC) is calculated for the previous six months and adjusted for periods of stock-outs. The current stock on

hand or physical inventory count is divided by AMC to determine how many months of stock were available.

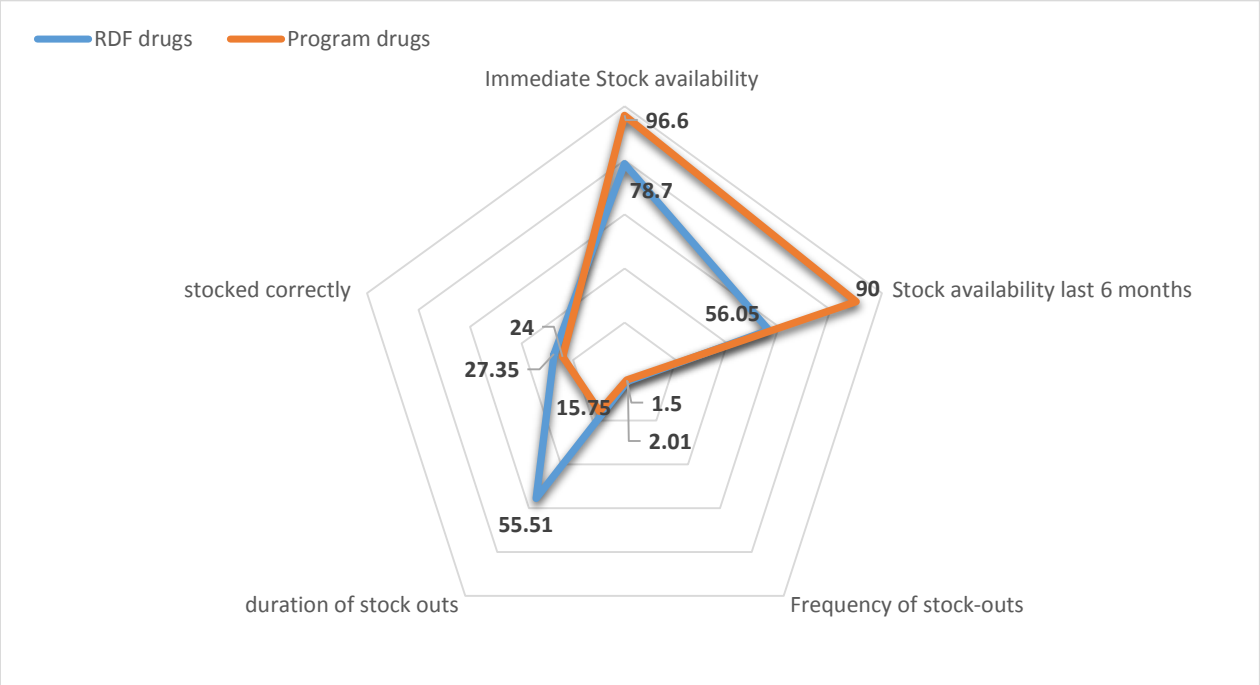
The result presented in figure 23.0, shows that most hubs are not stocked according to the recommended two to four months of stock. The percentage of hubs stocked correctly ranges between none of the hubs stocked correctly for products- (3 RDF and 1 Program) surgical glove, cimetidine, ciprofloxacin and RHZE and 83 percent for Nifedipine (RDF). For most products, only between 16-50 percent of hubs are stocked correctly. In most of the products assessed, understocking is more likely than overstocking. Most hubs are not stocked accordingly to the inventory policy of the agency: to hold a minimum stock of 2 times the AMC (Average Monthly Consumption) and a maximum stock of 4 times the AMC.

Figure 7; vital medicine stock on hand on the day of visit by product, April 2016



	Nifedipine 20mg tablet	Insulin zinc suspension 100IU/ml inj...	Chloramphenicol Sodium Succinate 1g...	Erythromycin (as Stearate) tablet - 25...	Gauze Surgical 90cmx100 mmesh...	Surgical gloves sterile latex No. 7.5	T.A.T. 1500 IU/ml injection	Cimetidine 200mg/ml, 2ml injection	Cotrimoxazol Suspension 240mg/5ml	Amoxicillin 250mg,500mg tablet	Ciprofloxacin 500mg Tablet	Lamivudine 300mg/Tenofovir 300mg...	Zidovudine 300mg/Lamivudine 15...	RHZE (150mg+75mg+400mg+275mg) , RH...	Artemether + lumefantherine (20+1...	Medroxyprogesterone acetate 150mg...
More than 4 months(Overstocked)	1	0	2	3	0	0	1	1	1	3	2	0	1	1	2	1
2-4 months(Stocked Correctly)	5	1	2	2	1	0	1	0	2	1	0	1	2	0	3	1
Less than 2 months(Understocked)	0	3	1	0	4	2	2	4	2	2	2	5	3	5	1	3

Figure 8; Stock availability performance measures -RDF versus Program



Research question 1:

- *What is the supply chain performance of EPHCSS?*

Average availability of stock in six regional hubs is 84.4% for the basket of 16 commodities on the day of data collection. Of the 16 commodities, program drugs are with better availability than the RDF ones. Average stock availability in the past 6 months is down to 66.7 %. With the same pattern, program drugs are with better availability than RDF products for the past six months. The service level agreement of the focal company, PFSA, is to avail a 100% availability of products to the public(PFSA 2015). Unavailability of such vital products from any of the focal company hubs is therefore a critical issue to be considered and one indication of deviation from ultimate objectives of the hub that requires an immediate intervention.

In hubs that had a stock-out of a product at least once in the 6 months prior to the survey, the frequency of stock-out is from a range of one to four times in average. Stock-outs of 3 RDF products is very common with a frequency of 3 to 4.6 times. The frequency of program drugs stock-out is relatively lower. An average frequency of stock out for program and RDF products is 1.5 and 2 times respectively.

The average duration of stock-outs varied widely ranging from 10 to 147 days: with RDF products being the highest from 48 to 147 days out of stock while program drugs staying stock-out relatively better with an average of 16.5 days.

It is only one product which is correctly stocked in all hubs, and another one product where 83% of the hubs stocked it correctly. For 4 products, none of the hubs are stocked correctly. And for the rest of the products, 15 to 50% of the hubs are correctly stocked.

The findings for the existence-, frequency- and duration of stock-outs and the proper inventory management give a scientific indication for the validity of the empirical experience, which became a motivation and targeted areas for this study.

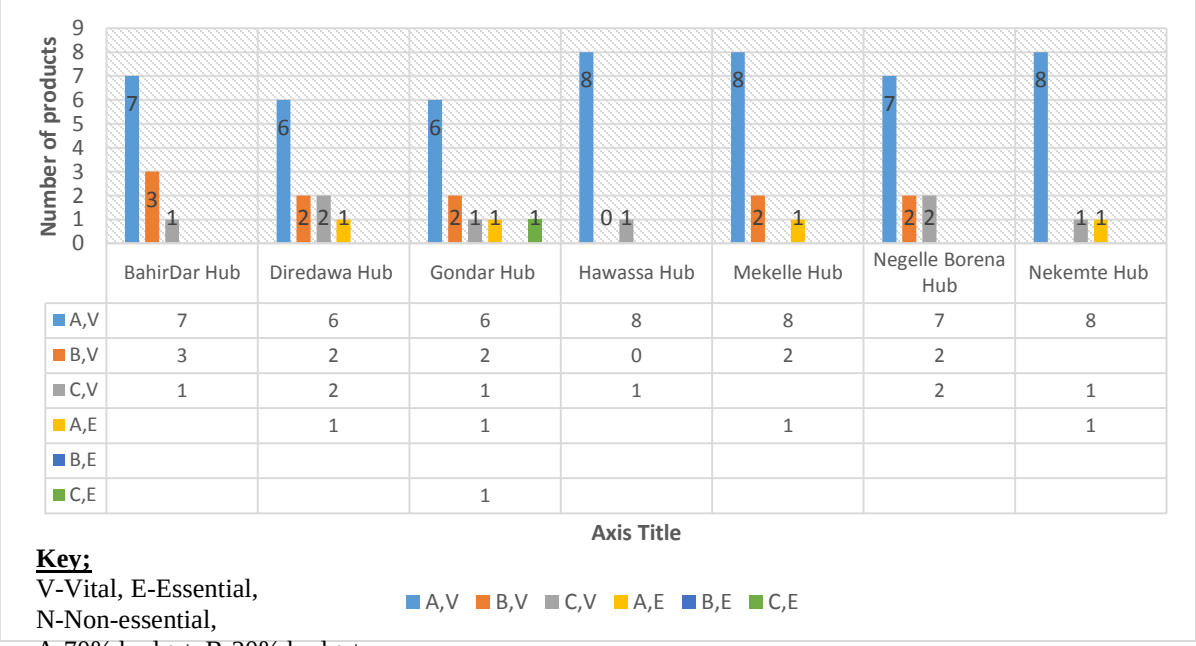
Generally, the results show performance gaps in product availability, which requires an immediate intervention. The interesting thing found is that of the relatively better availability and performance metrics for program drugs than the RDF ones. Even if the program drugs performance by itself requires improvements, but it would be a good opportunity to further find out in advance studies why the program drugs system of supply has relatively better qualities than the RDF categories for a benchmarking purpose.

3.2 Part II-Supply chain visibility

The visibility study in the system started with selecting a list of pharmaceuticals to study up on. Based on a pharmaceutical analysis report named VEN and ABC (a yearly categorizing of pharmaceuticals as **V**ital, **E**ssential and **N**on-essential and further cost analysis as, A-covering 70% of the budget, B-20% of the budget and C-10% of the budget) conducted by seven regional PFSA hubs (Bahir Dar, Diredawa, Gondar, Hawassa, Mekelle, Negelle Borena and Nekemte), a total of 11 products from the RDF product class were selected by the focal company forecasting team group as the top vital and highly consumed, and therefore are taken for this study.

1. Nifedipine 20mg tablet
2. Insulin zinc suspension 100IU/ml injection
3. Chloramphenicol Sodium Succinate 1gm injection
4. Erythromycin (as Stearate) tablet - 250 mg, 500mg
5. Gauze Surgical 90cmx100 m mesh size 19x15
6. Surgical gloves sterile latex No. 7.5
7. T.A.T. 1500IU/ml injection
8. Cimetidine 200mg/ml, 2ml injection - CSPC Ouyi Phar.
9. Cotrimoxazol (Sulphamethoxazole + Trimethoprim) Supension 240mg/5ml
10. Amoxicillin 250mg,500mg tablet
11. Ciprofloxacin 500mg Tablet

Figure 9; VEN and ABC standing for the selected 11 RDF pharmaceuticals



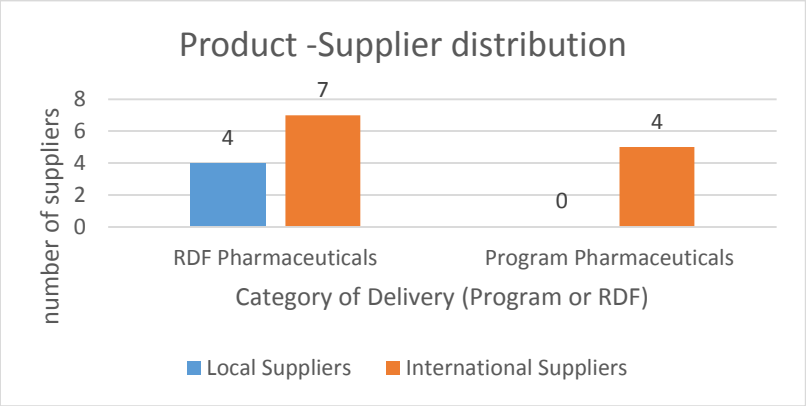
Key;
V-Vital, E-Essential,
N-Non-essential,
A-70% budget, B-20% budget,
C-10% budget

In case of the program pharmaceuticals, as there was no data analysis regularly made, five products, which has high number of clients, were selected from each product group(Anti-TB(1), Anti-Malarial(1), ARV(2), Family Planning(1)).

12. Lamivudine 300mg/Tenofovir 300mg/Efavirenz 600mg Tablet,
13. Zidovudine 300mg/Lamivudine 150mg/Nevirapine 200mg Tablet
14. RHZE (150mg+75mg+400mg+275mg) 0f 6x28 + RH- (150mg+75mg) of 12x28,Kit
15. Artemether + lumefanthrine (20 +120)mg 6X4,30
16. Medroxyprogesterone acetate 150mg/ml in 1ml,Vial

Therefore, a total of 16 pharmaceuticals were selected. These 16 products are supplied by 15 different suppliers; of which, four (4) are locally based while eleven (11) are international.

Figure 10; Local versus international suppliers supplying strength



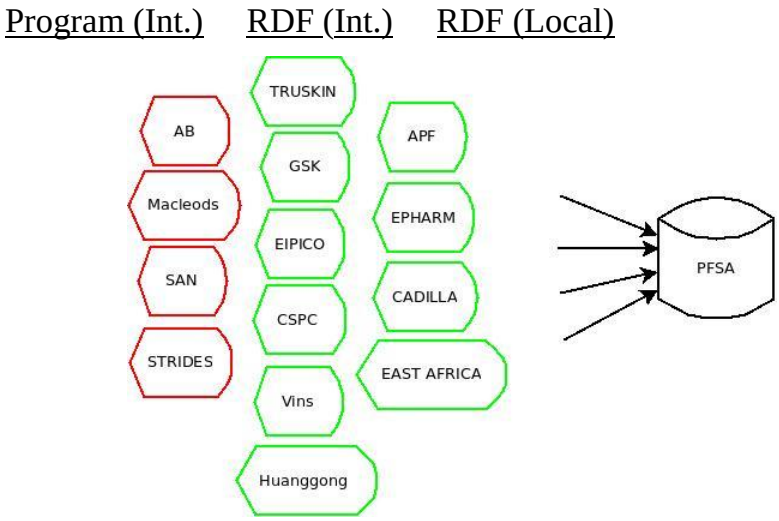
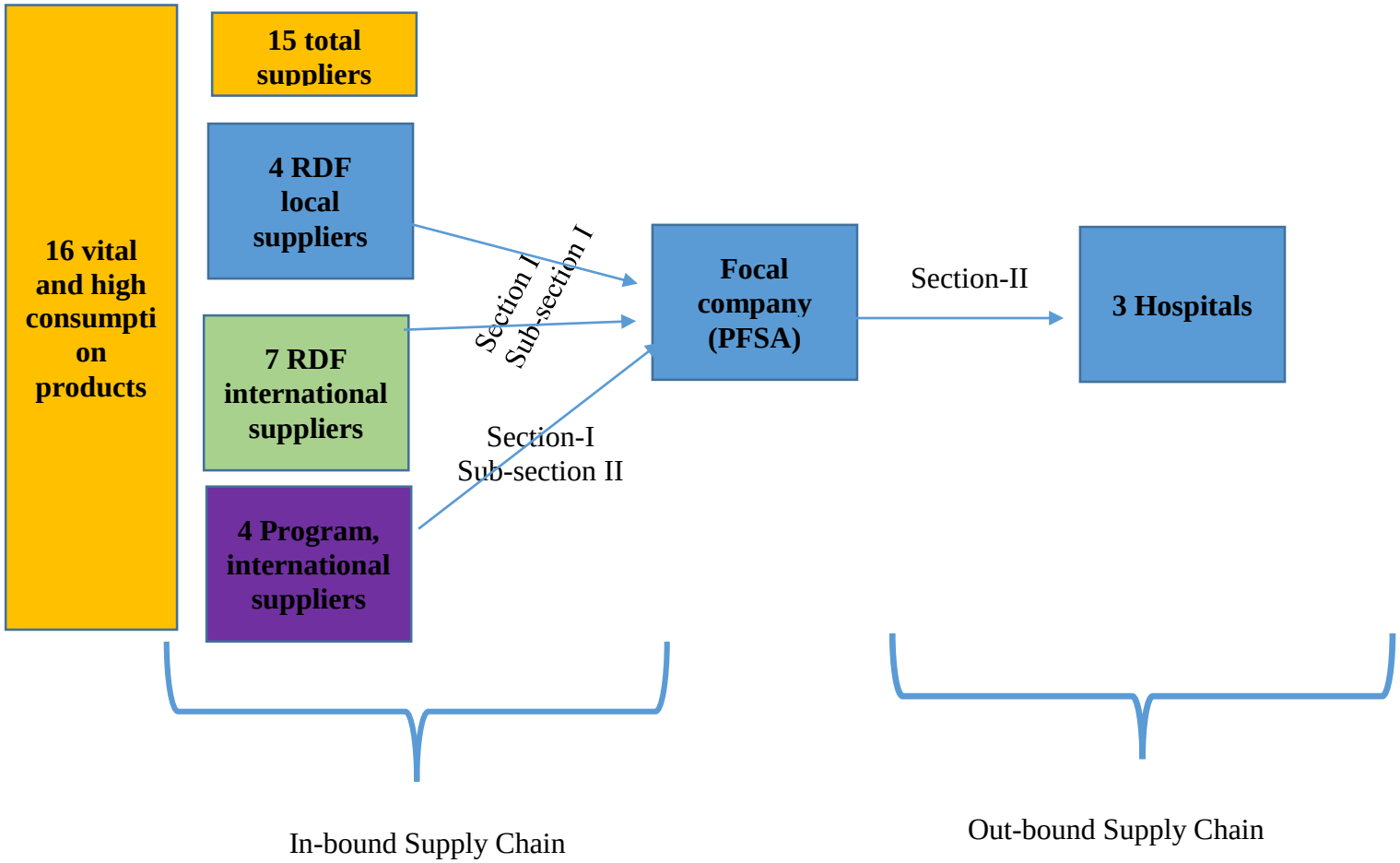


Figure 11; In-bound supply chain network, with the list of suppliers

3.2.1 Section-I, Inbound Supply Chain Visibility Measurement

3.2.1.1 Sub-Section- I // PFSA-RDF Suppliers

Figure 12; In-bound and outbound supply chain, partial visibility index overview



In a supply network, global visibility is a combination of the visibility that the focal company has of the different nodes of its inbound or outbound supply chain. Therefore, in order to have a global measure of supply chain visibility, the focal company's visibility of each node, i.e. a single supplier or a cluster of similar suppliers in terms of size and location is first calculated in this section and towards health institutions (the outbound) in section two.

The data exchange between two nodes regard different types of information, therefore as per the methodology, four types of information flows that the manufacturer exchange specific to the identified pharmaceutical product is identified out. The information flows gathered from the suppliers are quite the same for those members of suppliers within the international and local category.

Table 4; List of information within local and international suppliers of RDF products

	Type of Information flows							
Type of information flow generated	Transaction/Events		Status information		Master data		Operational plans	
Type of supplier	Local (11)	International (13)	Local (3)	International (2)	Local (7)	International (7)	Local (3)	International (3)
	1.Payment registered 2.Payment confirmed 3.Product demand captured 4.Production completed 5.Order received 6.Order confirmed 7.Order modified 8.Order packed for shipment 9.Order processed 10.Product sent 11.Production order sent	1.Payment registered 2.Payment confirmed 3.Product demand captured 4.Production completed 5.Product warehoused 6.Bid request issue 7.Client order received 8.Order confirmed 9.Order modified 10.Order packed for shipment 11.Order processed 12.Order shipped 13.Production order sent	1.Production in progress 2.Product ready for shipment 3.Product stock level	1.Production in progress 2.Product stock level	1.Product type 2.Stock keeping unit 3. Batch number 4. Manufactured date 5. Expired date 6. Shelf life 7. Hub name for shipment		1.Production quantity and type 2.Forecasted production quantity 3. Planned production type planned	

Measuring the visibility of individual nodes

Quantity and quality judgements are collected for each type of information flow (i.e. transactions/events, status information, master data and operational plans) and for each supply chain node. The quantity and quality visibility is measured using three scales:

- The quantity of exchanged information (Table 14)
- The quality in terms of accuracy (Table 15)

- The quality in terms of freshness (Table 16).

The scales have four response levels (Annex 6.6). As far as freshness is concerned, different information flows have different requirements in terms of frequency of updating. Therefore, transactions/events are judged as "fresh" only if they are updated frequently, while master data are considered "fresh" even if the frequency of update is much lower than that for transaction/events. For this reason, the description associated to each response level in the freshness scale depends on the type of information flow analyzed (Annex 7.0).

Final vales, to judge and mathematically analyze the visibility of each type of information flow and feature (i.e. quantity, accuracy and freshness), are collected.

Table 5; The collected values for each type of information flow and feature

Suppliers		Graded value as per the metrics (Minimum value=1, Maximum value=4)			
	Scales	Transaction/Events	Status Information	Master Data	Operational Data
Local	Quantity	4	4	4	4
	Accuracy	3	3	3	4
	Freshness	1	2	1	2
International	Quantity	4	4	4	4
	Accuracy	3	2	3	3
	Freshness	1	1	2	2

Table 5 indicates that, the focal company accesses more than 75 % of the information that are exchanged within RDF local and international suppliers. The problem is when it comes to the quality of the access. The accuracy of how those information are accessed ranges from 2 to 4 while how fresh those information are accessed goes down to 1. To get a partial visibility value per node level, further mathematical estimations are done.

Mathematical estimation of visibility at each node level

1. Total amount of visible information $\text{Node\_visibility\_quantity}_k = \sqrt[4]{j_{q,t} \cdot jq, s \cdot j_{q,m} \cdot j_{q,o}}$

Node_Visibility_Quantity= $\sqrt[4]{(4x4x4x4)}$ = 4(local)

Node_Visibility_Quantity= $\sqrt[4]{(4x4x4x4)}$ = 4 (Int.)

2. Accuracy of the overall visible information $\text{Node\_visibility\_accuracy}_k = \sqrt[4]{j_{a,t} \cdot j_{a,s} \cdot j_{a,m} \cdot j_{a,o}}$

Node_Visibility_Accuracy = $\sqrt[4]{(3x3x3x4)}$ = 3.22(local)

Node_Visibility_Accuracy = $\sqrt[4]{(3x2x3x3)}$ = 2.71(Int.)

3. Freshness of the overall visible information $\text{Node\_visibility\_freshness}_k = \sqrt[4]{j_{f,t} \cdot j_{f,s} \cdot j_{f,m} \cdot j_{f,o}}$

Node_Visibility_Freshness = $\sqrt[4]{(1x2x1x2)}$ = 1.41 (local)

Node_Visibility_Freshness = $\sqrt[4]{(1x1x2x2)}$ = 1.41 (Int.)

4. Quality of the overall visible information $\text{Node\_visibility\_quality}_k = \sqrt{\text{Node\_visibility\_accuracy}_k \cdot \text{Node\_visibility\_freshness}_k}$

Node_Visibility_Quality = $\sqrt{(3.22x1.41)}$ = 2.13(local)

Node_Visibility_Quality = $\sqrt{(2.71x1.41)}$ = 1.95(Int.)

5. Overall visibility of type i of information ($i = t, s, m, o$) $\text{Node\_partial\_visibility}_{i,k} = \sqrt[3]{j_{q,i} \cdot j_{a,i} \cdot j_{f,i}}, \quad i = t, s, m, o$

Node_Partial_Visibility of *transaction/Events information flow* = $\sqrt[3]{(4x3x1)}$ = 2.28(local)

Node_Partial_Visibility of *transaction/Events information flow* = $\sqrt[3]{(4x3x1)}$ = 2.28(Int)

Node_Partial_Visibility of *status information, information flow* = $\sqrt[3]{(4x3x2)} = 2.88$(local)

Node_Partial_Visibility of *status information, information flow* = $\sqrt[3]{(4x2x1)} = 2$ (Int)

Node_Partial_Visibility of *Master Data information flow* = $\sqrt[3]{(4x3x1)} = 2.28$(local)

Node_Partial_Visibility of *Master Data information flow* = $\sqrt[3]{(4x3x2)} = 2.88$ (Int)

Node_Partial_Visibility of *Operational Data information flow* = $\sqrt[3]{(4x4x2)} = 3.17$(local)

Node_Partial_Visibility of *Operational Data information flow* = $\sqrt[3]{(4x3x2)} = 2.88$ (Int)

6. $\text{Node\_overall\_visibility}_k = \sqrt{\text{Node\_visibility\_quantity}_k \cdot \text{Node\_visibility\_quality}_k}.$

Node_overall_visibility = $\sqrt{(4x2.13)}$ = 2.91 (local)

Node_overall_visibility = $\sqrt{(4x1.95)}$ = 2.79 (Int)

Table 6; Node level partial visibility values summary for local and international suppliers

Minimum score=1, Maximum score=4

Node (Supplier)	Total amount of visible information	Accuracy of the overall visible information	Freshness of the overall visible information	Quality of the overall visible information	Overall visibility of				Node_Overall Visibility
	Node_visibility quantity	Node_visibility accuracy	Node_visibility freshness	Node_visibility quality	Transaction/ Events information	Status Infor.	Master data Inform.	Operational data Informa	
Local	4	3,22	1,41	2,13	2,28	2,88	2,28	3.17	2,91
International	4	2,71	1,41	1,95	2,28	2	2,88	2,88	2,79

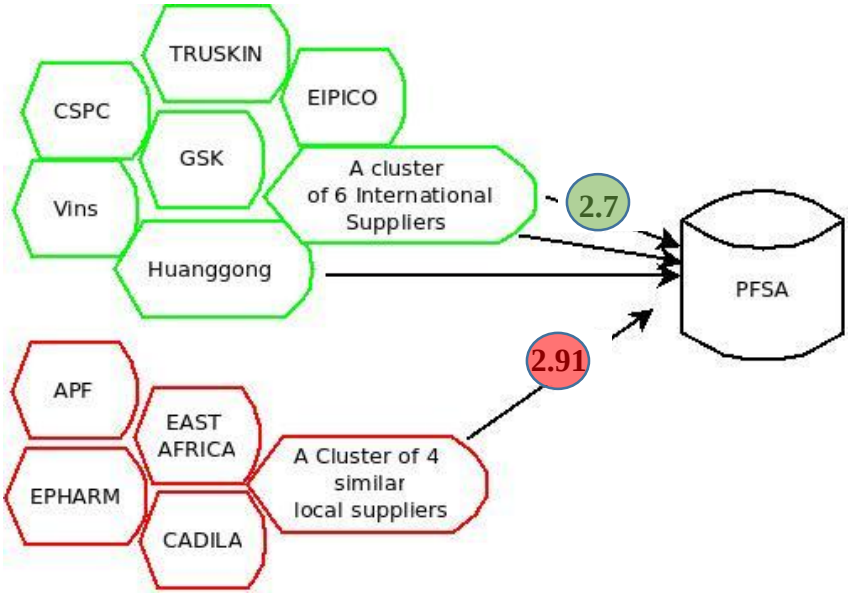


Figure 13; Focal Company's in-bound node partial visibility

Notes; Minimum score=1, Maximum score=4

Table five summarizes the quantity and quality of information accessing power of the focal company towards the two category of suppliers. The quality of information that is accessed is middle value below 2 towards international suppliers. The total partial visibility towards local suppliers is 2.91 better than international suppliers (2.7).The focal company has better visibility to the list of information types identified on table four, towards local suppliers than international suppliers under the RDF category.

Measuring the overall visibility

An overall measure of the supply chain visibility is obtained by combining the measures of visibility of the supply chain nodes. The contribution of each node to the overall measure is weighted on the basis of the criterias: Localization, significance and criticality (Annex 7.2).

For diagnostic purposes, the overall visibility index is broken down by information quantity and quality and by type of information flow, so further calculated with other more detailed indicators (Annex 7.3).

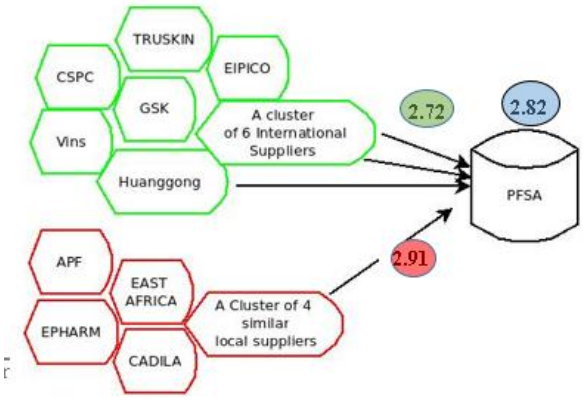
Over-all supply chain visibility estimation

Table 7; The computation of the weight of the node and overall supply chain visibility

List of suppliers for RDF pharmaceuticals based on the purchasing power	*Localization*	*Significance wsigk,*	*Criticality*	*Node weight based on table 11 (Wstd)* *(0 or* $\sqrt{(wloc.wsig)}$*)*	*Normalization (Wstd,k)*	*Node_overall_visibility*	*Supply chain_overall_visibility*
A cluster of local suppliers APF Epharm Cadilla East Africa	1	0.56317771	2	0.750452	0.3189	2,91	0.928132
Truskin Glove Pvt.Ltd	1	0.13304302	2	0.364751	0.1550	2,79	0.432508
Huanggang Hyangzhou	1	0.08697961	2	0.294923	0.1253	2,79	0.349709
CSPC Zhongnuo Pharmaceutical	1	0.08539222	2	0.292219	0.1241	2,79	0.346503
Egyptian International EIPICO	1	0.07219563	2	0.268692	0.1141	2,79	0.318606
GlaxoSmithKline (GSK)	1	0.04385033	2	0.209405	0.0889	2,79	0.248304
Vins Biopoducts LTD	1	0.01037521	2	0.101859	0.0432	2,79	0.12078
CSPC Ouyi Phar	1	0.00498627	2	0.070614	0.0300	2,79	0.083731
				2.352914			
						Supply_chain_overall_visibility ($\sum$)	2.8282

Table 7 shows procedures followed to reach an inbound overall (RDF) visibility with a final value of 2.82.

Figure 14; Inbound RDF global visibility



Notes; Minimum score=1, Maximum Score=4

3.2.1 Section-I, Inbound Supply Chain Visibility Measurement

3.2.1.2 Sub-Section- II // PFSA-Program Suppliers

The type of information flows, the program pharmaceutical suppliers generate and exchange, is quite the same as what is discussed above. This is because those suppliers, which normally supply RDF drugs, are also into the business of program drugs manufacturing. In addition to that, the standard of procedures and manufacturing practices are common amongst suppliers regardless of the product type.

Therefore, the capacity of the focal company in accessing those information exchanges from these suppliers is graded (Annex 7.3) and final values which is used to judge and mathematically analyze the visibility of each type of information flow and feature (i.e. quantity, accuracy and freshness) is collected.

Figure 15; The collected values for each type of information flow and feature, program suppliers

Minimum score=1, Maximum Score=4

	Transaction/Events	*Status Information*	*Master Data*	*Operational Data*
Quantity	4	4	4	4
Accuracy	3	3	3	3
Freshness	1	2	2	2

Calculating visibility at a node level

1. Total amount of visible information $\text{Node\_visibility\_quantity}_k = \sqrt[4]{j_{q,t} \cdot j_q, s \cdot j_{q,m} \cdot j_{q,}}$

Node_Visibility_Quantity= $\sqrt[4]{(4x4x4x4)} = 4$

2. Accuracy of the overall visible information $\text{Node\_visibility\_accuracy}_k = \sqrt[4]{j_{a,t} \cdot j_{a,s} \cdot j_{a,m} \cdot j_{a,o}}$

Node_Visibility_Accuracy = $\sqrt[4]{(3x3x3x3)} = 3$

3. Freshness of the overall visible information $\text{Node\_visibility\_freshness}_k = \sqrt[4]{j_{f,t} \cdot j_{f,s} \cdot j_{f,m} \cdot j_{f,o}}$

Node_Visibility_Freshness = $\sqrt[4]{(1x2x2x2)} = 1.68$

4. Quality of the overall visible information $\text{Node\_visibility\_quality}_k = \sqrt{\text{Node\_visibility\_accuracy}_k \cdot \text{Node\_visibility\_freshness}_k}$

Node_Visibility_Quality = $\sqrt{(3x1.68)} = 2.24$

5. Overall visibility of type i of information $(i = t.\ s.\ m.\ o)$ $\text{Node\_partial\_visibility}_{i,k} = \sqrt[3]{j_{q,i} \cdot j_{a,i} \cdot j_{f,i}}, \quad i = t, s, m, o$

Node_Partial_Visibility of *transaction/Events information flow* = $\sqrt[3]{(4x3x1)} = 2.28$

Node_Partial_Visibility of *status information, information flow* = $\sqrt[3]{(4x3x2)} = 2.88$

Node_Partial_Visibility of *Master Data information flow* = $\sqrt[3]{(4x3x2)} = 2.88$

Node_Partial_Visibility of *Operational Data information flow* = $\sqrt[3]{(4x3x2)} = 2.88$

6. $\text{Node\_overall\_visibility}_k = \sqrt{\text{Node\_visibility\_quantity}_k \cdot \text{Node\_visibility\_quality}_k}.$

Node_overall_visibility = $\sqrt{(4x2.24)} = 2.99$

Table 8: Node level partial visibility values summary (Program suppliers)

Minimum score=1, Maximum score=4

Node (Supplier)	Total amount of visible information	Accuracy of the overall visible information	Freshness of the overall visible information	Quality of the overall visible information	Overall visibility of				Node overall visibility
	Node_visibility quantity	Node_visibility accuracy	Node_visibility freshness	Node_visibility quality	Transaction/ Events information	Status Infor.	Master Data Inform.	Operational Data Infora	
Local	4	3	1.68	2.24	2,28	2.88	2.88	2.88	2,99

Table 8 indicates that the focal company accesses more than 75% of the information exchanged within program suppliers in a better quality (2.24) than towards RDF suppliers (2.13), even though freshness of access is still lower (1.68).

Unlike the RDF inbound estimations, there is no need of calculating an overall inbound measure of the supply chain visibility for program line suppliers as they are already clustered as a group. Which means, the already calculated partial visibility can represent the global inbound visibility towards program suppliers. However, the inbound global visibility constituting both the RDF and Program suppliers is calculated considering RDF international suppliers, RDF local suppliers and Program suppliers' node partial visibility values and their significance weights. A detailed value of the index is then broken down by information quantity, quality and by type of information flow for diagnostic purposes, with other more detailed indicators, (Annex 7.4).

Figure 16; Summary of the inbound supply chain visibility

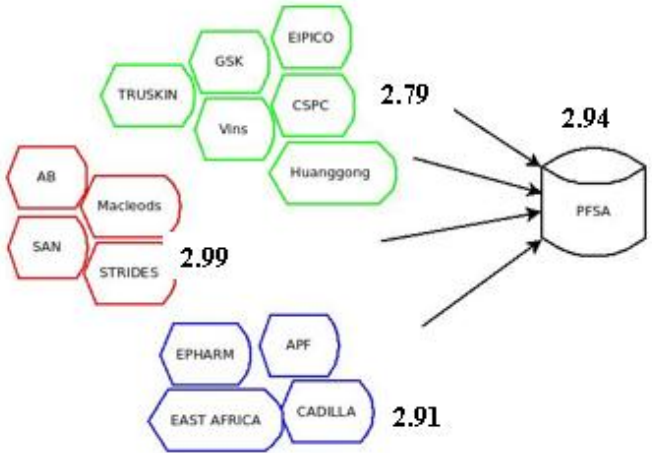


Figure 16 summarizes the partial visibility values at each node and the final inbound global visibility. Partial visibility of the focal company towards RDF international suppliers is the lowest with a value of 2.79(4 maximum value), 2.91 towards RDF local suppliers and 2.99 towards program suppliers. The geometric average of the global inbound visibility value being 2.94.

3.2.2 Section-II, Outbound supply chain visibility measurement

3.2.2.1 Sub-Section- I // PFSA-Hospitals (RDF)

The focal company PFSA, has an extensive line in its outbound supply chain serving more than 3547 health centers, 311 hospitals and 6,200 health posts (out of the 16,440-where the rest are supplied through health centers) across the country. From such a complex network, three hospitals are selected based on;

- Number of patients they serve
- Level of service (Specialization)

for studying the outbound visibility of the focal company.

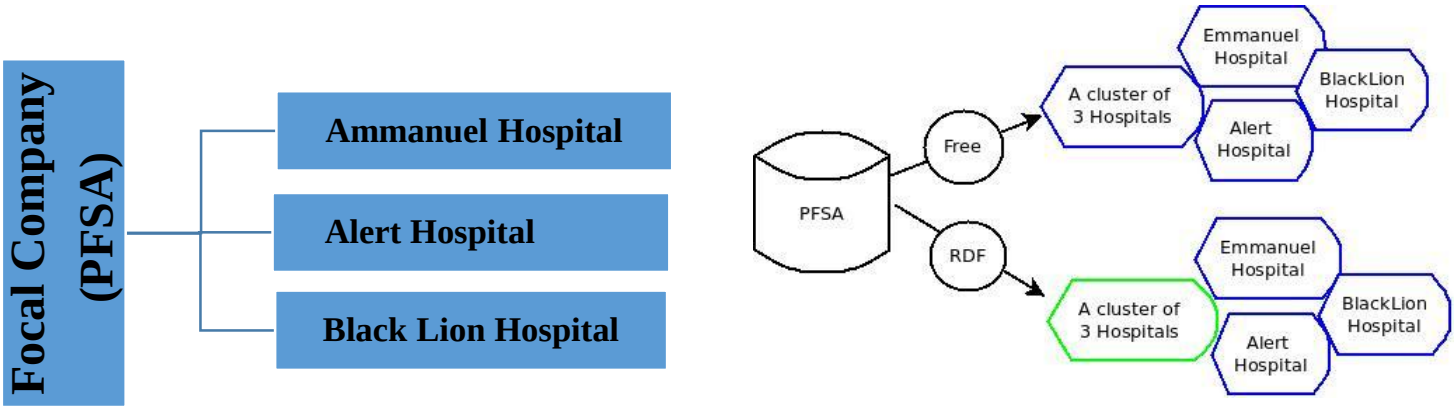


Figure 17; Focal companies out-bound supply chain

To find out what information are exchanged within the hospitals under the RDF (Purchase) service supply chain, the activity diagram of, mainly referred as APTS –Auditable Pharmaceuticals Transactions and Services- a system of practice nowadays commonly getting implemented in bigger hospitals is mapped,(Annex 7.5).

For the identified information which are exchanged within the hospitals, 'how well they are accessed' by the focal company is measured from the quantity and quality perspective. Before measuring, the information exchanges are categorized into the four categories.

Twelve kinds of transaction/event, six status, seven master data and two operational kind of information are exchanged within the selected hospitals.

From the master datas, only the information 'Stocked out product lists by date' and 'SKU-stock keeping unit' are accessed, while all the status information and operational plan datas are accessed. From the transaction/events, two of the information exchanges are not accessed. The one shaded below are information, which are not accessed by the focal company. It is found out that all the communications or the means of data access by the focal company is through telephone, e-mails and letter.

Transaction/Events: (12)
When purchase is happening

- Purchase order generated
- Purchase order sent
- Payment initiated
- Payment Completed
- Transaction Completed
- Product is issued from Special Pharmacy
- Product is Issued from Main pharmacy
- Stocked out product requested
- Warehouse stock issued
- Pharmacy outlet stock refilled
- Warehouse Product received
- Drug Stock Status Updated

Status Information (6)
Instant standing status of a drug

- Main Pharmacy Stock out
- Special Pharmacy Stock out
- Warehouse Stock out
- Main Pharmacy Stock level
- Special Pharmacy Stock Level
- Warehouse Stock level

Master Data: (7)

- Patient/Client Personal Information
  - ✓ Name, Age and Address
- Patient/Client Financial Information
  - ✓ Free Patient/client status
  - ✓ Cash paying Client
  - ✓ Credit Client
- Patient Diagnosis
  - ✓ Patient VS's by date and time
  - ✓ Patient/Client clinical history
- Patient Case
  - ✓ Clinical finding
  - ✓ Laboratory assessment, findings
- Prescription Information
  - ✓ Drug name, ROA, Strength
  - ✓ Days of treatment
  - ✓ Physician Information
- Product stock keeping unit
  - ✓ Vial, Ampoule,100x10 box, 10x10p 6x4pk, Kit, of 30 tin/box, of 60 tin/bo of 100 tin/box,
- Stocked out product lists by date

Operational Plans (2)

- Near expiry transfer plan
- Expired and damaged items disposal plan

The information that are exchanged within hospitals, as the figure above shows, are very key and relevant to affect business processes. Not being able to access those information or being able to access them but with poor accuracy and freshness will surely have consequences.

The grading of each information type is collected for analysis *(Ann*ex 7.6) of the partial outbound node visibility.

Table 9; the collected values for each type of information flow and feature, focal company's accessing potential towards information exchanged within hospitals in the RDF supply line

Minimum score=1, Maximum score=4

	Transaction/Events	*Status information*	*Master data*	*Operational data*
Quantity	3	4	2	4
Accuracy	3	2	2	2
Freshness	1	1	1	2

Calculating visibility at a node level

1. Total amount of visible information $\text{Node\_visibility\_quantity}_k = \sqrt[4]{j_{q,t} \cdot jq, s \cdot j_{q,m} \cdot j_{q,o}}$

   Node_Visibility_Quantity= $\sqrt[4]{(3x4x2x4)}$ = 3.13

2. Accuracy of the overall visible information $\text{Node\_visibility\_accuracy}_k = \sqrt[4]{j_{a,t} \cdot j_{a,s} \cdot j_{a,m} \cdot j_{a,o}}$

   Node_Visibility_Accuracy = $\sqrt[4]{(3x2x2x2)}$ = 2.21

3. Freshness of the overall visible information $\text{Node\_visibility\_freshness}_k = \sqrt[4]{j_{f,t} \cdot j_{f,s} \cdot j_{f,m} \cdot j_{f,o}}$

   Node_Visibility_Freshness = $\sqrt[4]{(1x1x1x2)}$ = 1.18

4. Quality of the overall visible information $\text{Node\_visibility\_quality}_k = \sqrt{\text{Node\_visibility\_accuracy}_k \cdot \text{Node\_visibility\_freshness}_k}$

   Node_Visibility_Quality = $\sqrt{(2.21x1.18)}$ = 1.61

5. Overall visibility of type i of information $\text{Node\_partial\_visibility}_{i,k} = \sqrt[3]{j_{q,i} \cdot j_{a,i} \cdot j_{f,i}}, \quad i = t, s, m, o$ $(i = t, s, m, o)$

   Node_Partial_Visibility of *transaction/Events information flow* = $\sqrt[3]{(3x3x1)}$ = *2.06*

   Node_Partial_Visibility of *status information, information flow* = $\sqrt[3]{(4x2x1)}$ = *1.99*

   Node_Partial_Visibility of *Master Data information flow* = $\sqrt[3]{(2x2x1)}$ = *1.58*

   Node_Partial_Visibility of *Operational Data information flow* = $\sqrt[3]{(4x2x2)}$ = *2.51*

6. $\text{Node\_overall\_visibility}_k = \sqrt{\text{Node\_visibility\_quantity}_k \cdot \text{Node\_visibility\_quality}_k}.$

   Node_overall_visibility = $\sqrt{(3.13x1.61)}$ = 2.24

Even if PFSA is still able to access most of the information that is exchanged within hospitals (more than 75 of it), the quality of access is still an issue where those key information are accessed late.

3.2.2 Section-II, Outbound supply chain visibility measurement

3.2.2.2 Sub-Section- II // PFSA-Hospitals (Program)

Likewise the RDF supply line, to find out what information are exchanged within the hospitals under the Program supply line, the activity diagram of, IPLS –Integrated Pharmaceuticals Logistics System- is mapped(Annex 7.7) and the kind of information are identified.

The list of information that are exchanged within the hospitals are listed, categorized and measured from the quantity and quality perspective: Seven kinds of transaction/event, seven status, six master data and four operational kind of information exchange within the selected hospitals.

Transaction/Events: (7)
When purchase is happening

- Order generated
- Order sent
- Warehouse Product refilled
- ART Pharmacy stock refilled
- Emergency stock requested
- Emergency stock refilled
- Patient registry is updated

Status Information (7)
Instant standing status of a drug

- ART Pharmacy Stock out
- Warehouse Stock out
- ART Pharmacy Stock level
- Warehouse Stock level
- Product expired
- Product Damaged
- Product reached '*less than 6 months*' expiry

Master Data: (6)

- Patient/Client Personal Information
  - ✓ Name, Age and Address
- Patient Diagnosis
  - ✓ Patient VS's by date and time
  - ✓ Patient/Client clinical history
  - ✓ Laboratory assessment by date and time
- Patient Treatment Information
  - ✓ Treatment drug lines
  - ✓ First time/ refill
  - ✓ Treatment history
- New Prescription Information
  - ✓ Drug name, ROA, Strength, Batch
  - ✓ Days of treatment
  - ✓ Physician Information
- Product stock keeping unit
  - ✓ Vial, Ampoule,100x10 box, 10x10pk, 6x4pk, Kit, of 30 tin/box, of 60 tin/box, of 100 tin/box,
- Stocked out product lists by date

Operational Plans (4)

- Near expiry transfer plan
- Expired and damaged items disposal plan
- Weekly inter-facility request
- Monthly outer-facility product requisition

The grading of each information type is collected for analysis *(Ann*ex 7.8) of the partial outbound node visibility.

Table 10; the collected values for each type of information flow and feature, focal company's accessing potential towards information exchanged within hospitals in the Program supply line

Minimum score=1, Maximum score=4

	Transaction/Events	*Status information*	*Master data*	*Operational data*
Quantity	4	4	4	4
Accuracy	3	3	2	2
Freshness	1	3	1	2

Calculating visibility at a node level

1. Total amount of visible information $\text{Node\_visibility\_quantity}_k = \sqrt[4]{j_{q,t} \cdot j_{q,s} \cdot j_{q,m} \cdot j_{q,o}}$

   Node_Visibility_Quantity= $\sqrt[4]{(4x4x4x4)} = 4$

2. Accuracy of the overall visible information $\text{Node\_visibility\_accuracy}_k = \sqrt[4]{j_{a,t} \cdot j_{a,s} \cdot j_{a,m} \cdot j_{a,o}}$

   Node_Visibility_Accuracy = $\sqrt[4]{(3x3x2x2)} = 2.44$

3. Freshness of the overall visible information $\text{Node\_visibility\_freshness}_k = \sqrt[4]{j_{f,t} \cdot j_{f,s} \cdot j_{f,m} \cdot j_{f,o}}$

   Node_Visibility_Freshness = $\sqrt[4]{(1x3x1x2)} = 1.56$

4. Quality of the overall visible information $\text{Node\_visibility\_quality}_k = \sqrt{\text{Node visibility accuracy}_k \cdot \text{Node visibility freshness}_k}$

   Node_Visibility_Quality = $\sqrt{(2.44x1.56)} = 1.95$

5. Overall visibility of type i of information $(i = t, s, m, o)$ $\text{Node\_partial\_visibility}_{i,k} = \sqrt[3]{j_{q,i} \cdot j_{a,i} \cdot j_{f,i}}, \quad i = t, s, m, o$

   Node_Partial_Visibility of *transaction/Events information flow* = $\sqrt[3]{(4x3x1)} = 2.28$

   Node_Partial_Visibility of *status information, information flow* = $\sqrt[3]{(4x3x3)} = 3.29$

   Node_Partial_Visibility of *Master Data information flow* = $\sqrt[3]{(4x2x1)} = 1.99$

   Node_Partial_Visibility of *Operational Data information flow* = $\sqrt[3]{(4x2x2)} = 2.51$

6. $\text{Node\_overall\_visibility}_k = \sqrt{\text{Node\_visibility\_quantity}_k \cdot \text{Node\_visibility\_quality}_k}.$

   Node_overall_visibility = $\sqrt{(4x1.95)} = 2.79$

The findings from the above estimation shows PFSA's better access of information towards hospitals in the program supply line (2.79) than the RDF supply line (2.24).At the same time, the quality of information access has grown from 1.61(during the RDF supply line) to 1.95(during the program supply line). All the values of visibility so far calculated are collected in figure 19 for further discussion regards to the research question.

Outbound Visibility

RDF =2.24

T	S	MD	OD
2.06	1.99	1.58	2.51

Quantity				Accuracy				Freshness			
3.13				2.21				1.18			
T	S	MD	OD	T	S	MD	OD	T	S	MD	OD
3	4	2	4	3	2	2	2	1	1	1	2

Program =2.79

T	S	MD	OD
2.28	3.29	1.99	2.51

Quantity				Accuracy				Freshness			
4.0				2.44				1.56			
T	S	MD	OD	T	S	MD	OD	T	S	MD	OD
4	4	4	4	3	3	2	2	1	3	1	2

Inbound Visibilitv

Global Inbound= 2.94

T	S	MD	OD
2.28	2.78	2.79	2.83

Quantity				Accuracy				Freshness			
4				2.99				1.6			
T	S	MD	OD	T	S	MD	OD	T	S	MD	OD
4	4	3	4	3	2.8	3	3.1	1	1.8	1.8	2

Program =2.99

T	S	MD	OD
2.28	2.88	2.88	2.88

Quantity				Accuracy				Freshness			
4.0				3				1.68			
T	S	MD	OD	T	S	MD	OD	T	S	MD	OD
4	4	4	4	3	3	3	3	1	2	2	2

RDF =2.82

T	S	MD	OD
2.28	2.28	2.68	2.97

Quantity				Accuracy				Freshness			
4.0				2.87				1.4			
T	S	MD	OD	T	S	MD	OD	T	S	MD	OD
4	4	4	4	3	2.3	3	3.3	1	1.3	1.6	2

Local (RDF) =2.91

T	S	MD	OD
2.28	2.88	2.28	3.17

Quantity				Accuracy				Freshness			
4.0				3.22				1.41			
T	S	MD	OD	T	S	MD	OD	T	S	MD	OD
4	4	4	4	3	3	3	4	1	2	1	2

International (RDF) =2.79

T	S	MD	OD
2.28	2	2.88	2.88

Quantity				Accuracy				Freshness			
4.0				2.71				1.4			
T	S	MD	OD	T	S	MD	OD	T	S	MD	OD
4	4	4	4	3	2	3	2	1	1	2	2

Figure 18; Final outbound and inbound global and partial visibility values summary tree

Minimum score=1, Maximum score=4

Research question 2:

- *How is Supply Chain Visibility implemented in EPHCSS?*

The study shows that in the inbound supply chain, the focal company has a better partial visibility (2.99/4) with regard to foreign suppliers of program pharmaceuticals than with the local suppliers (2.91) and international suppliers (2.79/4) of RDF pharmaceuticals.

Even if more than 75 % of all the information flow within the inbound suppliers is accessed by the focal company, but the accuracy of the accessed information is of intermediate score (2.9/4)and the freshness is indeed very poor (1.6/4). Operational data are those information flows accessed with better accuracy and freshness while transaction/events information flows with least freshness score. Accessing in a relatively better accuracy and freshness, the production quantity and forecasted type of products by a supplier might be important for the focal company but it is not as important as freshly and accurately accessing the status and transaction information when it comes to improving their supply chain performance. By accurately and freshly knowing the status of their orders, the stock status and the production amount in progress of their suppliers -the focal company could make informed decisions to avoid stock-outs .

Comparatively similar result is recorded in the outbound portion where information flows within hospitals for the program pharmaceuticals supply line are better accessed(more than 75% accessed) but with moderate quality; accuracy (2.44/4) and freshness (1.56/4) than the RDF supply line; accessibility (3.13/4),accuracy (2.21/4) and freshness (1.18/4).

In both of the situations, the hubs does not have a better freshness and accuracy visibility index to the transaction and status information of health institutions which probably contributes to the poor supply chain performance indexes: frequent and high duration of stock-outs at health facilities. In order to avoid the buildup of unused stock, and intervene stock-outs at both facility and hub level at its earliest stage, the hubs need to know the real time true consumption and stock level progress of facilities: the status and transaction information accurately and freshly. In the finding, the overall visibility of transaction and status information is relatively lower in the case of RDF supply line (T (2.06/4), ST (1.99/4)) than the Program supply line (T (2.28/4), ST (3.29/4)). Having a

better visibility of facilities product status information contributes to a better decision making and better performance which is shown by the correlation of program drugs better visibility, better performance and better availability of products than the RDF ones. Accessing accurate and fresh status information at facility level would help hubs to quantify and forecast the true demand of lower levels and therefore could mitigate the bullwhip effect, (Zhao et al. 2002).

There are key things understood from the findings. Primarily, there is a relatively better visibility within the Program supply line. The RDF supply chain shall find out what current practices and working procedures has made the program supply line relatively better to benchmark their scores to line up by taking diagnostic measures. Secondly, as discussed above on the sequence, as long as the information we want it visible are critical and key for decision making and can have the potential to trigger better supply chain performances , both the RDF and program supply lines shall strive to find possible ways and shall implement optimization and automation of their processes to enhance their supply chain visibility: to boost the freshness and accuracy of their current information access pattern which is found to be poor according to the findings of this study.

3.3 Part III-Improvement approaches to enhance the visibility

3.3.1 Section-I: Process model design, improvement point's identification and approaches

To identify reasons for insufficient supply chain visibility within the study system and figure out points for improvement possibilities, a time series analysis of chronological sequence is done.

Basing on the insights from the case study, a process model is designed coherent of the individual supply chain process steps and actors of the system. Designing the process model helped to identify unused potentials for transparency improvements and needs for recommending approaches. Therefore on the process model, between different actors within the processes, many points are identified which are critical for the creation of the research problems. Almost all of these processes are manually performed as also indicated by percentage of orders placed through electronic ordering system analyzed on analysis-I, very few of the processes are already supported by appropriate technologies (I would rather say, only data base management systems are so far in use), therefore require the support of more economic friendly approaches.

In order to provide supply chain visibility, it is obvious and crucial to implement process automation. Through automation and technical support, thus, improvement potentials can be resulted.

Before suggesting the derived visibility improvement approaches, points of tension areas-those contributing to the creation of the research problems and analysis of improvement points are presented based on the process model design.

The process model is designed into three categories of major processes; to delicately represent the supply chain processes of the system.

1. Quantification for national procurement (Process diagram 1-figure 20)

Under this division are those process activities from quantification of pharmaceutical products until a contracting is signed with a supplier and consequent follow-ups. It shows the overall processes involved in procurement of pharmaceuticals by the focal company-PFSA. Everything starts from health facilities as they play the primary role in quantifying their total annual needs. It is then the duties of the regional PFSA hubs to summarize the reports/annual purchase requests of health facilities and forward it to the central hub FCB (forecasting and capacity building) unit as

an aggregated annual hub requirement (AAHR). The PD (procurement department) unit of central PFSA get into the practices of supplier selection, contracting and procurement.

2. Procurement Supply and Request refill (Process diagram 2)

This portion of the diagram originates from the manufacturer, as a continuation of the first portion, whereby the central PFSA (Importer) is supplied with the products ordered. Then the next figures show the refill/supply of stock to the lower levels until a single pack of medicine is dispensed to the end-customer.

3. Stock refill (Purchase) Request (Process diagram 3)

Here are only two actors accounted: health facilities and regional PFSA hub. This part dictates the IPLS product refill or purchase request by the health facilities to regional PFSA hub. And at the same pace, regional PFSA hubs stock refill request to their next higher tier: Central PFSA.

Points identified out

For each of the research problems, the tension process areas are identified out.

3.3.1.1 Poor inventory management [IM]

- Frequent product stock-outs
- Inventory overstock

The process activities labeled with IM, are those supply chain processes which (from the insight of the case-study, literature reviews and part-I findings) are found out to be contributing factors for the frequent stock-outs and inventory overstock.

3.3.1.1.1 Under the category of '*Quantification for national procurement*'

IM1 Annual demand *quantification* at the health facilities level

The quantified demand of pharmaceuticals from public health facilities is the basis for the agency's procurement plan. The quantification is theoretically based on factors like; past consumption data, morbidity profile, demographic data and yearly budget of the health facility. It is mainly the decision of the health professional (pharmacy head) to search for the input data figures and feed in the APR (annual purchase request). There are minimal ways the upper tier could prove whether the APR coming from facilities is in fact calculated based on consumption data. In the process of generating APR based on consumption method, health facilities also consider stock out periods,

service expansion or contraction and possibilities of future increase in demand based on specific situation in their catchment – which makes the quantification more of an estimation.

IM2 The *collection, analysis, evaluation* and aggregation of APR at the regional PFSA

Gaps in the accuracy of the quantification estimation at the regional PFSA hubs which take into effect lower tier requests is also an issue. Demands of non-governmental health facilities (whose demand is unreal, swinging and shown creating bullwhip effect within the supply chain) is included in to the aggregated annual requirement of the hub, where private importers and wholesalers fail to satisfy.

IM3 *Final analysis* with *VEN and ABC* by Central PFSA FCB

The final quantification coming from the hubs which passed through many uncertainties, the 'aggregated annual hub requirement ', is itself analyzed by the central PFSA FCB against many uncontrolled variables: planned health service expansion, past consumption, stock-out periods, service statistics and budget reference.

Therefore, from this category and the above three main tension areas; two contributing factors to the mentioned problem are identified out

- Inaccurate and inadequate data availability for quantification during the yearly procurement
- Budget constraints

3.3.1.1.2 Under the category of '*Procurement supply and refill'*

These constitute supply chain processes for the delivery of the product to the focal company which already is ordered and stock refill constitute those processes where the stock is to be processed from a stocked inventory to be issued to lower tiers. The following key processes from this category are found out to be responsible for the research problem of poor inventory management.

IM4 *Order processing* at the pharmaceutical manufacturer

Even if pharmaceutical suppliers fill rate is good, but other factors like longer lead time and emergency production incapacities contribute to stock-outs or overstock inventories at the lower level.

The stock quantification and analysis part at this sub-class require consumption trend of facilities and their genuine stock request data. Inaccurate and inadequate data feed to the processes create the research problems later on.

IM5 *Quantification and rationing* at central PFSA

IM6. *Analysis and rationing* at regional PFSA

3.3.1.1.3 Under the category of '*Stock-refill request*'

IM7/8. Stock request processing at health facilities and regional PFSA

3.3.1.2 Counterfeit products within the legitimate supply chain [CO]

The process activities labeled with CO, are those supply chain processes which (from the insight of the case-study and literature reviews) are possible gateways for counterfeited products into the legitimate chain.

CO1. Selection of suppliers at Central PFSA PD

Those suppliers who have a contact with sub-standard drug makers may compete for a bid. Therefore, selection of suppliers could be one key area for a gateway of counterfeit medicines.

CO2. Delivery by the pharmaceutical manufacturer

The key inflows and outflows of counterfeit and sub-standard medicines are in-between this steps after the legitimate manufacturer shipped their original products but which are diverted and exchanged with the fake ones on the journey.

CO3/4. Stock receive and delivery to the lower tiers at the central and regional PFSA

Receive are also common gateways where hubs unknowingly or deliberately receive on route exchanged counterfeit medicines which later go down and consumed by the end-user.

3.3.1.3 Poor traceability of product [Tr]

The process activities labeled with '**Tr'**, are those supply chain process points through which a (from the insight of literature reviews and similar studies) product can be tracked/traced when there is a drug-recall.

Tr1. The point of exit from the pharmaceutical manufacturer

This process steps are the first tracking points where the manufacturer is able to register each product that is getting out of its unit. Having accurate and real-time data here is a vital requirement.

Tr2/3/4/5/6/7. GRV recording or HCMIS/Bin /Stock card updates at central, regional PFSA and health facilities when a product is received

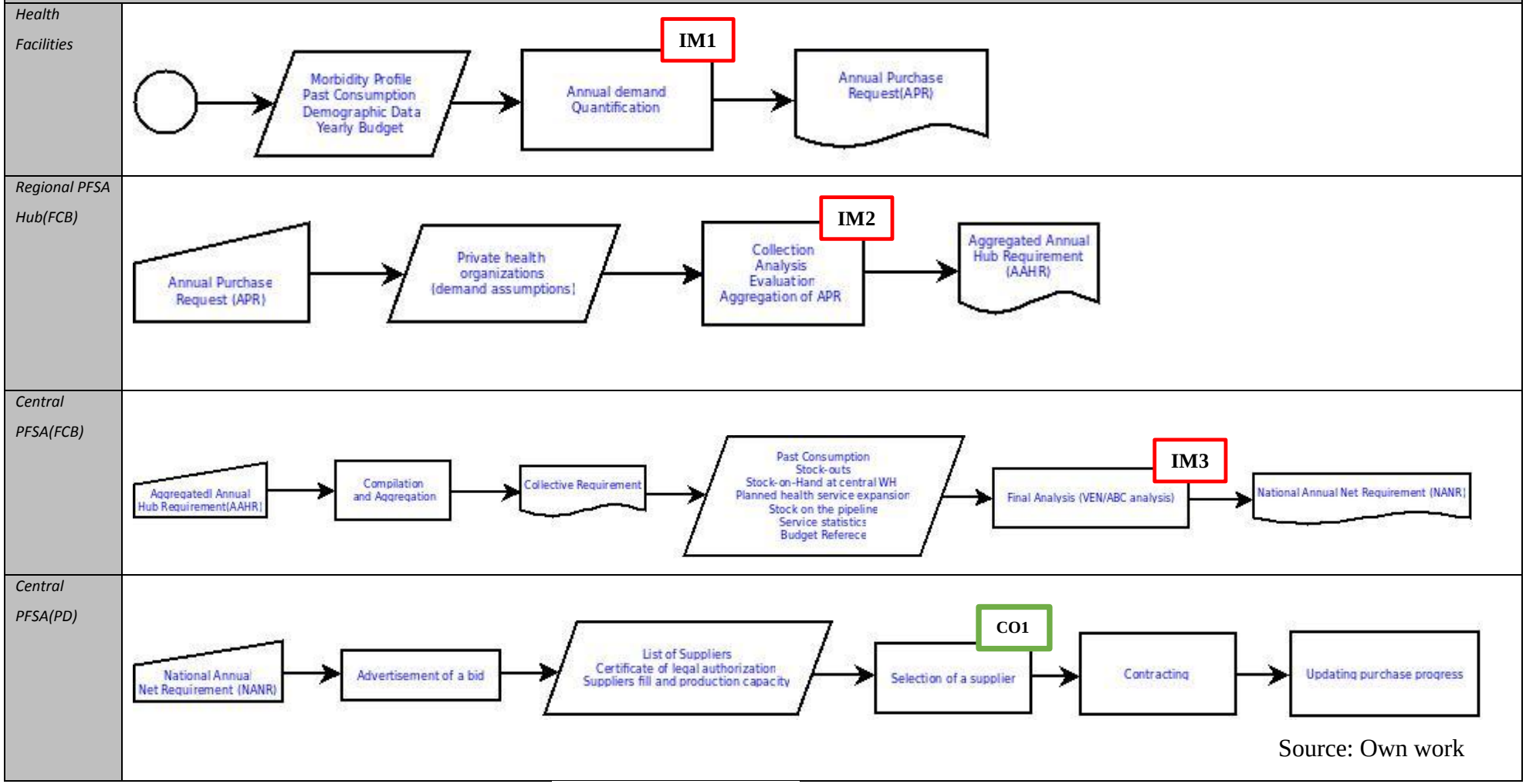
Facilities including the importer and regional wholesalers and health facilities manually and electronically register (database except health facilities) the product specification they receive and issue. But as the data input method is mainly manual, and the actors rely more on paper records, tracing of a given product at some instant time is hectic.

Tr8. Bin-card updates (done every time a product is issued to a patient) at the health facility level

The story is the same for the health facilities' too. The big unique thing here is that, the patient information who took a specific drug could never be traced as there is no registry made about patient information by the time of a drug dispense. At the same time, records for an issue of a drug to an end-user is not made.

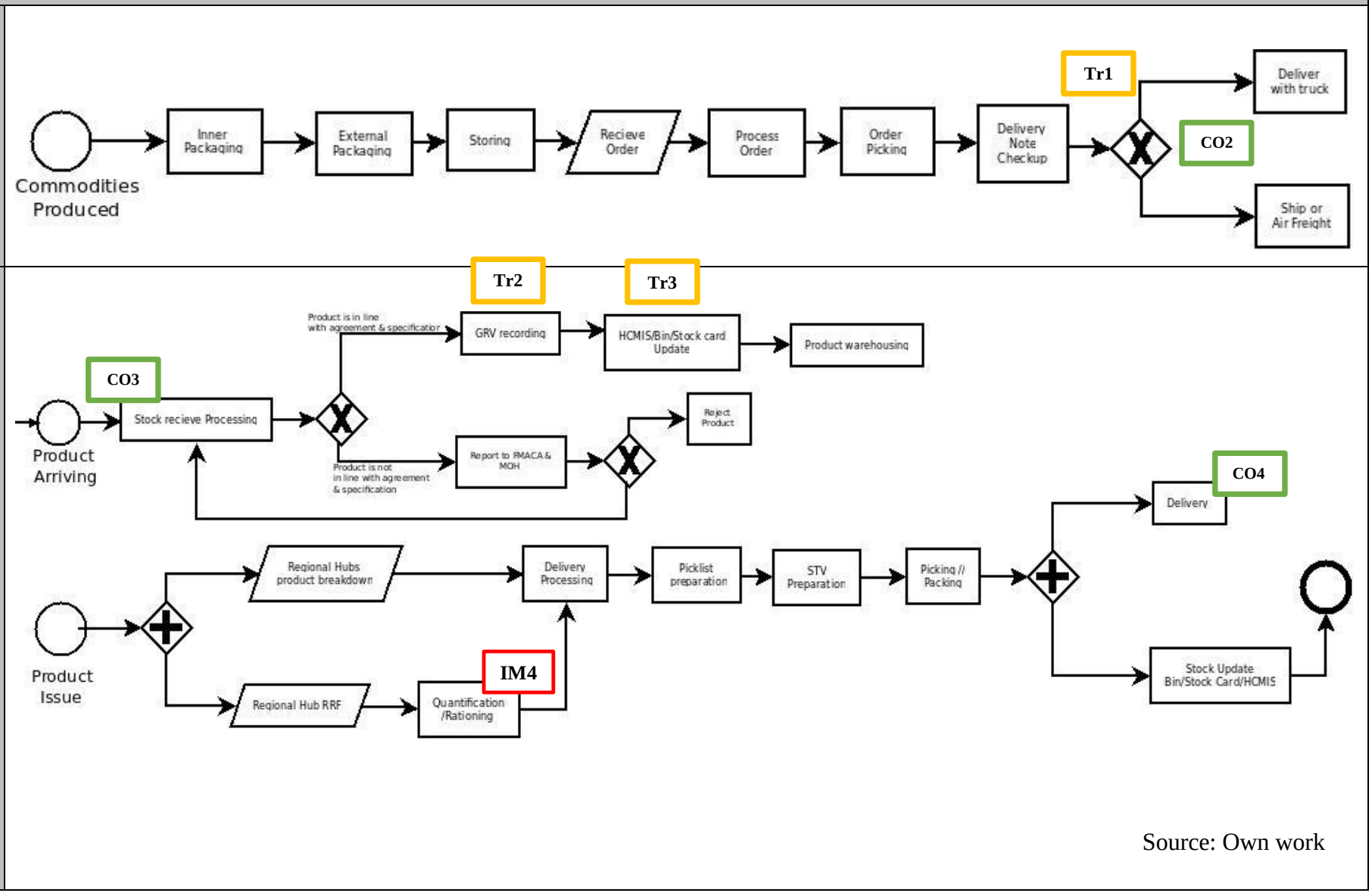
Process model design and Improvement point's identification

Figure 19: Process Diagram 1- Quantification for national procurement



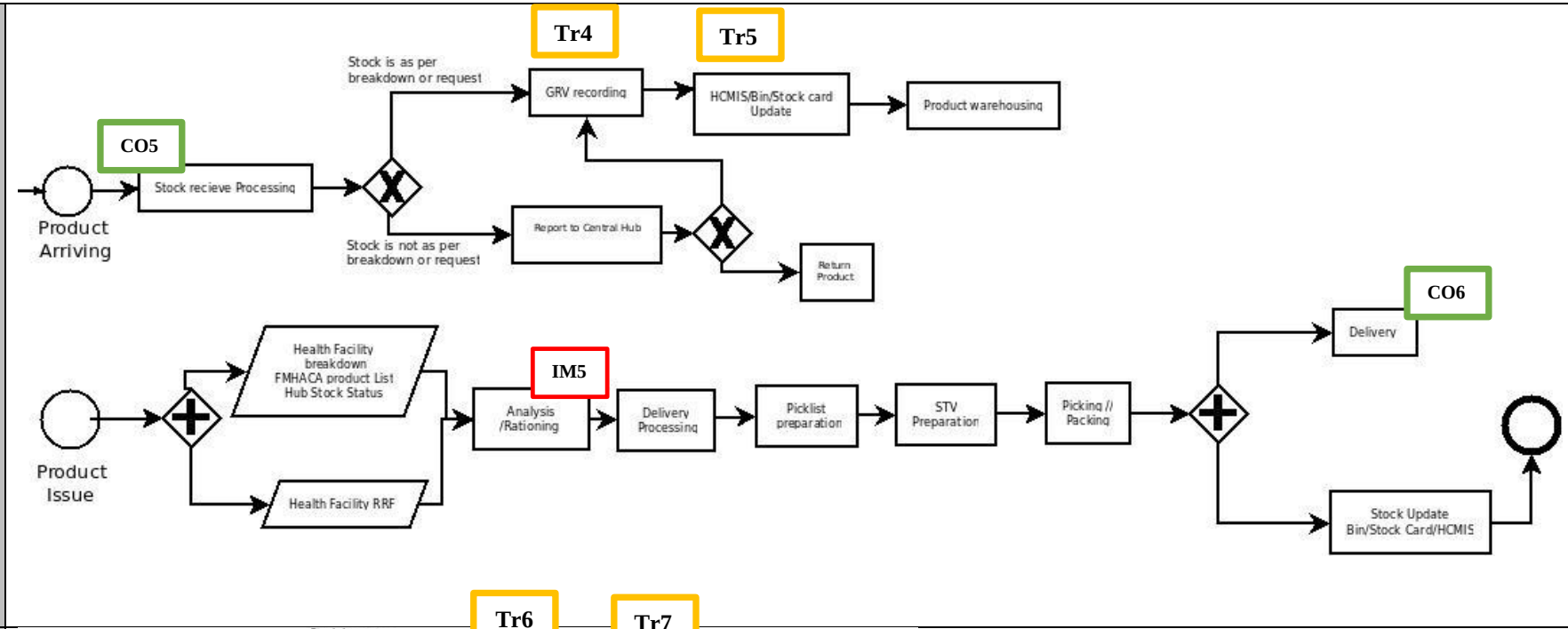
Source: Own work

Figure 20: Process Diagram 2- Procurement Supply and Request Refill (based on IPLS)

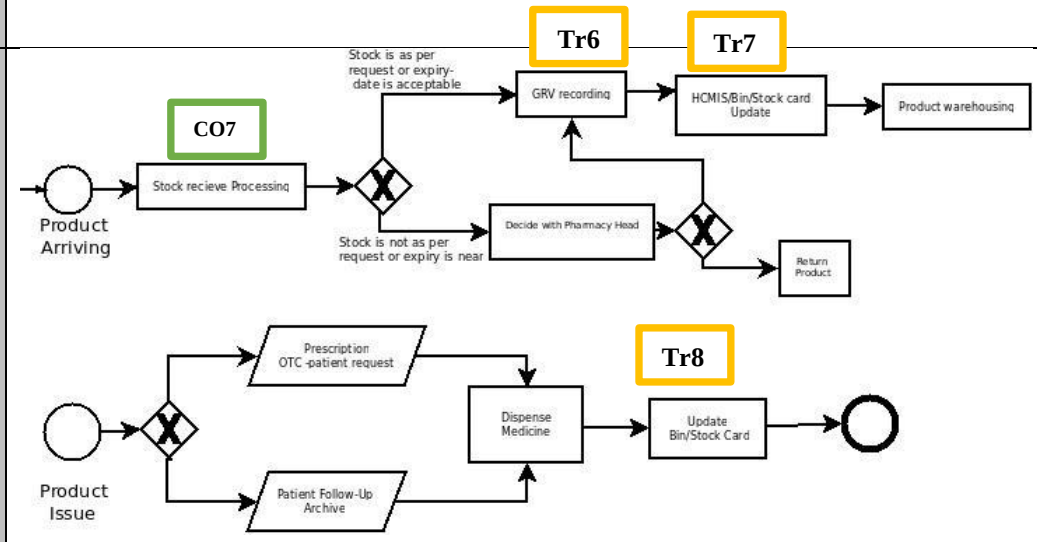


Source: Own work

Regional PFSA (Wholesaler)



Health Facilities

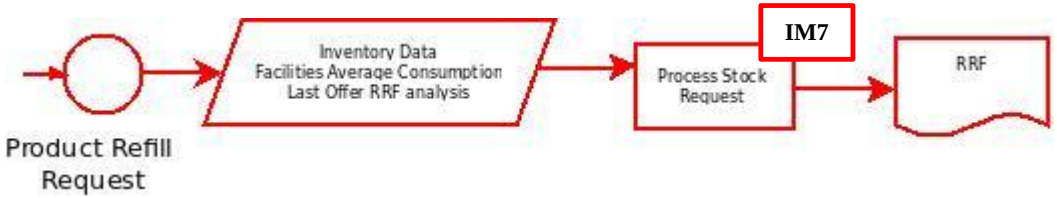


Source: Own work

Figure 21: Process Diagram 3- Stock refill (Purchase) request

Health Facilities

Regional PFSA Hub



Source: Own work

3.3.2 Section-II; Recommended approaches

Based on the insight of the case study, reference of similar projects and cases from the literature and my advisors personal expertise; the following sub-chapters present two improvement approaches for targeting the tension areas and for accessing the potentials.

Research question 3:

- *What are those approaches through which the supply chain visibility could be improved under the constraints of EPHCSS?*

Primarily, GS1 Data matrix barcoding unique identification and database authentication system for efficient tracking and tracing of items and shutting off counterfeit and sub-standard drugs smuggle into the system. Secondly, a real-time inventory dashboard which is automatically linked with the scanning system and the already established system database management (HCMIS) to mitigate inventory management challenges are the two approaches this study recommends.

3.3.2.1 GS1 Data Matrix Unique identification and database authentication system

Standard-based pharmaceutical traceability solution enables stakeholders to capture and share defined product information between trading partners, increasing the security of the extended supply chain. Labeling packets with GS1 will secure the pharmaceutical supply chain against counterfeiting by giving actors the capability and confidence in confirming the legitimacy of the products they receive, (GS1 July 2015).

The key components needed to be deployed for this improvement approach are two things:

GS1 Data matrix labeling;

GS1 data matrix is a key data carrier chosen as it is emerging across the world as the preferred data carrier in health care, due to the fact that it can hold the same amount of data as a linear data carrier but takes up less space whilst providing error detection and correction capabilities.

For this system, GS1 matrix is better to be structured to carry four element strings with related application identifiers (AIs): Highest level of AIDC (automatic identification and data capture) marking.

- GTIN (Global Trade item Number)
- AI (01) –Unique identification for the manufactured drug
- Expiration date AI (17)

- Batch Number AI (10)
- Random Serial Number AI (21) –Randomized, non-sequential event serialization for every single pack

In the production phase, the manufacturer prints a unique GS1 Data matrix code symbols on the product packaging.

Database application Platform Copying/Updating

The second requirement is to have a database where those unique codes are to be stored every time a product is manufactured so that they could then be accessed by lower tier actors.GS1 has its own global data synchronization network (push database system). For security purposes, having a primary database accessed only by manufacturers and a secondary database accessed by many actors within the chain (importer-PFSA main hub, wholesaler-regional hubs, and health institution pharmacies) for authentication purposes would be safer.

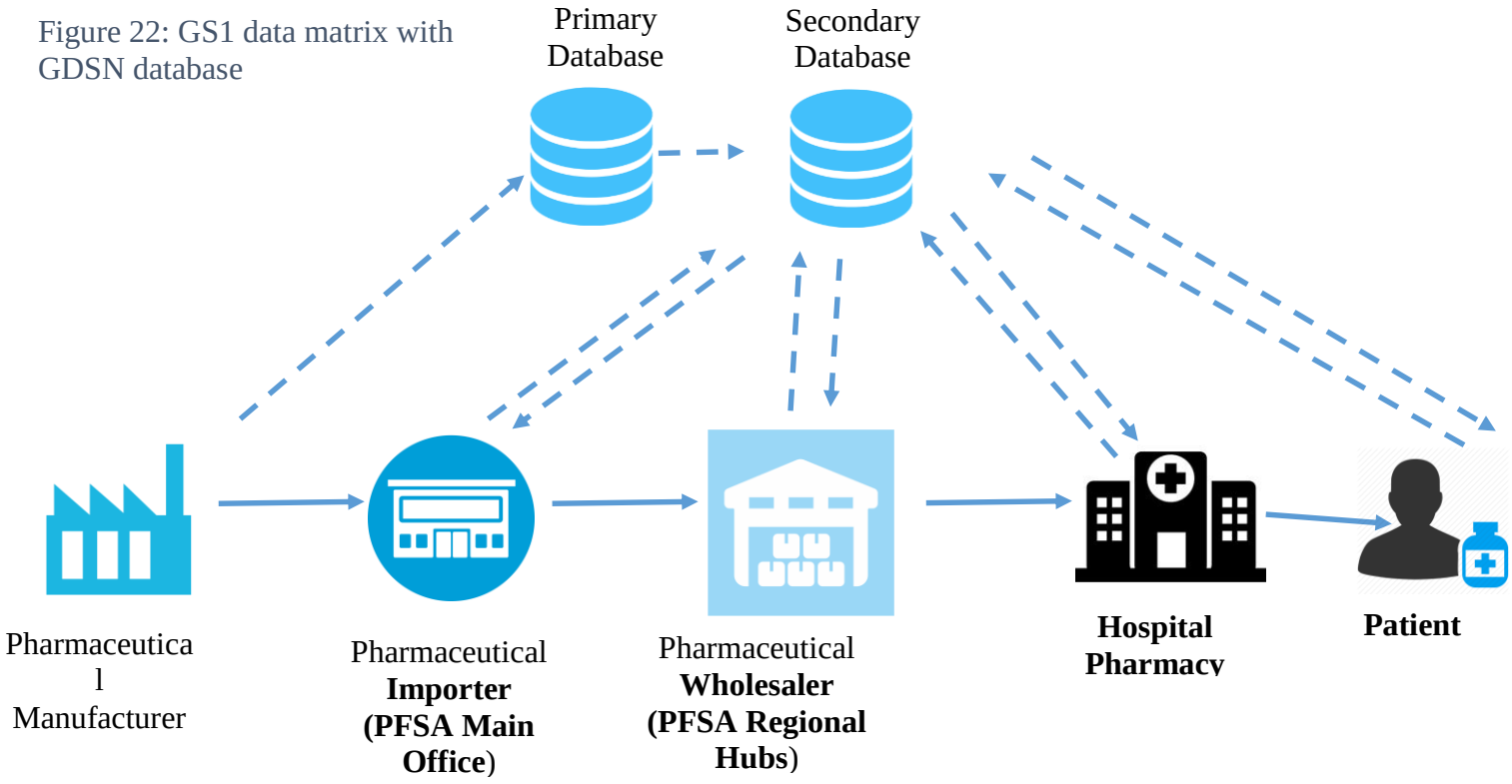
After the codes are labeled, the 4 data elements (GTIN, expiration date, batch no. and serial no) and related information (e.g. active ingredient and/or drug specifications) will be uploaded to a primary database application platform accessed by manufacturers.

The code is then copied on a second database, which is accessed, by the importer, wholesaler and health institutions. When product cartons are dispatched from the manufacturer, all related information are updated and shared on the platform and can be accessed by the importer, wholesaler and pharmacies (health institution).

The database is modeled on GDSN (Global Data Synchronization) standard, holding the master data of each medicine (GTIN).

The importer, wholesaler and pharmacies can authorize the items they receive by checking the codes on the packages through scanning from the GDSN every time they receive orders for authentication.

Figure 22: GS1 data matrix with GDSN database



Even though the GS1 integrated data matrix coding could ensure the system with unique identification and securing of the chain, but from the insights of the case study we also see two practical issues which need to be considered here;

1) To authenticate product packages, every code has to be scanned before receive, which would become unideal to do in cases where the actors transact bulk number of items each day(considering GS1 data matrix- which require a direct line of contact for scanning for each of the tagged product). This bulk product movement is a day to day activity, therefore the warehouse professionals may become reluctant in authenticating products and may receive the stocks without any scans/authentication. This creates a gap and a good opportunity for the counterfeited drugs to surge into the system.
2) Automatic identification technologies like the RFID codes which doesn't require a direct contact of scanning and able to scan bulk items at ones are very suitable for such a problem but that would be difficult to implement it at the item level on the current system mainly for two reasons:

The first is the cost of each electronic tag, which would make most medicines prohibitively expensive and place them outside the boundaries of established price ceilings, both government and market imposed. Secondly and perhaps the greatest impediment to item-level tagging by RFID is that the consumer does not carry RFID readers to decode the radio

signal thereby fails to include the consumer in the authentication process. But RFID may probably be considered for high-value products by undergoing ROI (return on investment) further studies.

Therefore, what we suggest in addition to the GS1 data matrix authentication is an implementation of an end-user enabled authentication system platforms.

Referring to projects in India, Malaysia and the European union,(Gupta, K. Singhal, and Pandey. 2012, Afify and Mabrouk 2013 , Sinha 2012),end-user authentication can also be possible even with the GS1 data matrix identification where every strip of medicine available ought to have a unique randomly generated numeric code – AI (21) and where the end-user (clients) can SMS the code and a message referring to the database will tell the consumer whether the drug is original or not.

The inner medicine stripes –each one of them will have a unique randomly generated numeric code and labeling (primary packaging). This is the code to be messaged (SMS) by the user.
E.G 100 strips (10tabs) of amoxicillin will have their own unique number

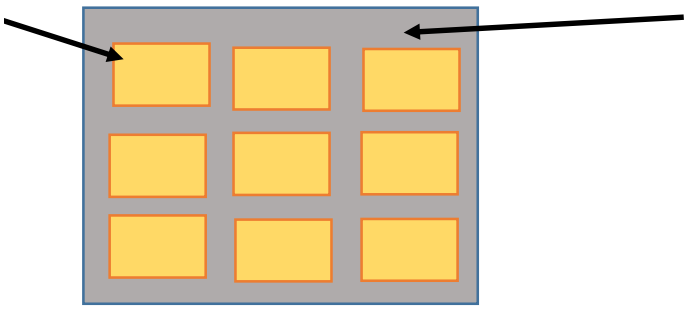


Figure 23: GS1 data matrix code package marking

The outer box package will have one GS1 label (Case and multi-pack labeling. This is the code to be scanned by pharmaceutical importer/wholesaler/pharmacies at the time of receive
E.G a Box of 1000 tabs (100stripes x10tabs) of amoxicillin will have one outer GS1 code

After a customer confirmed the codes through sms, the unique codes are then decrypted from the database as 'used'. There will be extremely little incentive for the counterfeiters to steal the unique codes from legitimate supply chain packages of products because it will be tiresome for them to wander and steal the unique codes per the simplest dispense unit. As a second implementation strategy, and basing on further studies, the unique codes can be tamper-evident (scratch-off labels) which need to be unveiled only during messaging,(mPedigree 2016). mpedigree which is already practical in Nigeria, Ghana, Kenya can be a good alternative of tamper-evident codes and authentication.

Authenticating drugs until the tip point of pharmacies may not be enough in cases like Africa or Ethiopia because smuggled drugs may deliberately be sold by pharmacies (Health institutions) as long as they find it cheap and profitable to sell, (Sahle et al. 2012). Therefore, the extra purpose of enabling the public with a friendly and easy to use self-authentication of

medicine legitimacy is a key implementation portion. Enabling clients(end-user) themselves who are always vigilant about fake drugs to check authenticity just within few seconds of user-friendly service closes the gaps; at least lives could be saved.

3.3.2.2 An Integrated Inventory Dashboard linked with the scanning system and the already in-use company inventory database management (HCMIS)

One of the most important motivations behind any integrated supply chain management is to eliminate the barriers by enabling the synchronization and sharing of valuable information among stakeholders. The success of the whole process depends on the level of the visibility of the pharmaceuticals at each hub, suppliers, and health institutions in a common interface for responsible professionals. The improved visibility of such information coupled with informed decision making would yield significant benefits in inventory management, resource utilization and product distribution,(Delen et al. 2011, Wang, G., and Wei 2007).

The second proposal therefore deals with a dashboard .The data matrix scanning has not to be merely for authentication purposes, but also as a gateway to the status update of products on a dashboard interface. Immediately when an item is authenticated, the inventory data is recorded/updated in the dashboard. The same is true when an item is issued out. So that being at a central level (PFSA main hub), decision makers and professionals could real-time look at the inventory data of regional hubs and health facilities. The integration of the currently existing HCMIS inventory management systems at hubs, with the automatic data input from the data matrix scanning would make data entry to an electronic stock control easy and fast. What we have figured out from the case study is that, hubs HCMIS is updated late even after receive of a stock. Primarily the hubs give high consideration to paper receive documents (GRV- goods receiving voucher). The reason we found out is that,

1) The items hubs receive need to be first sorted out in item name, product amount, batch number, expiry date: so that store professionals prefer to sort the items on a former easy to use paper receiving formats before they electronically feed the data into the HCMIS-which sometimes take even weeks.

Therefore, we believe creating the link between code identification and HCMIS data input avoids the gap here and will change the manual data feeding: By the time a product is scanned, it shall appear on the HCMIS screen, and that change is immediately synched to a separate web-based interface-inventory dashboard from the HCMIS data base.

From the case study, we found out that the system already has a web-based inventory dashboard (which shows inventory data of those eleven hubs which use the HCMIS hub edition) which communicates with the HCMIS. But the main problem issues are three;

1) It is not real-time, it doesn't show the updated inventory data as the HCMIS itself is updated late due to the problems of data-feeding mentioned above.
2) Health facilities data is not visible on the dashboard, there are few facilities using the facility HCMIS based edition.
3) Organizational: Even for the data already available on the web-based dashboard, visually triggered proactive decision making is very poor. E.g figure 27 below shows that from a sample of three hubs discussed at part-I, Bahir-dar hub has lots of vital product varieties stocked-out at that exact moment where those items are overstocked in Jimma and Adama hubs, where organizational measures hasn't been taken where the stock out days stayed from (5, 25 days duration- same until the last date of data collection). The ultimate outcome of having visibility boosting solution is to make an informed decision making which requires a sustained organizational commitment.

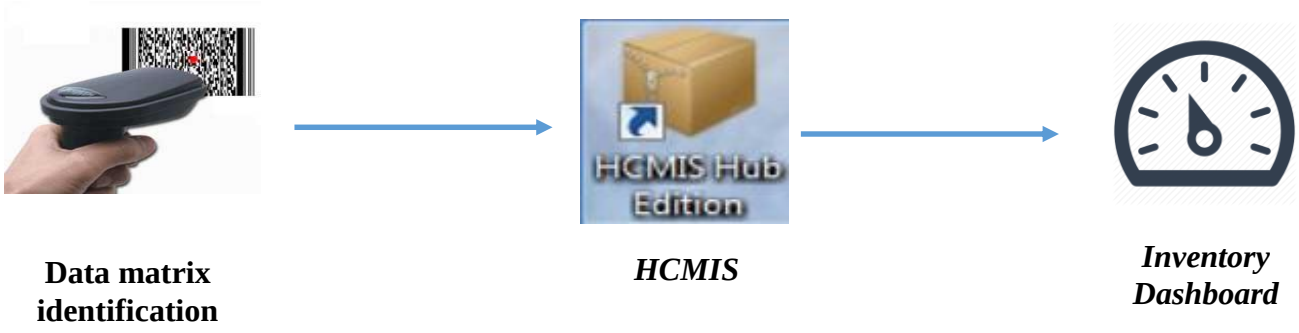


Figure 24: Processes linked; Data matrix scanning, HCMIS data input, Inventory dashboard update

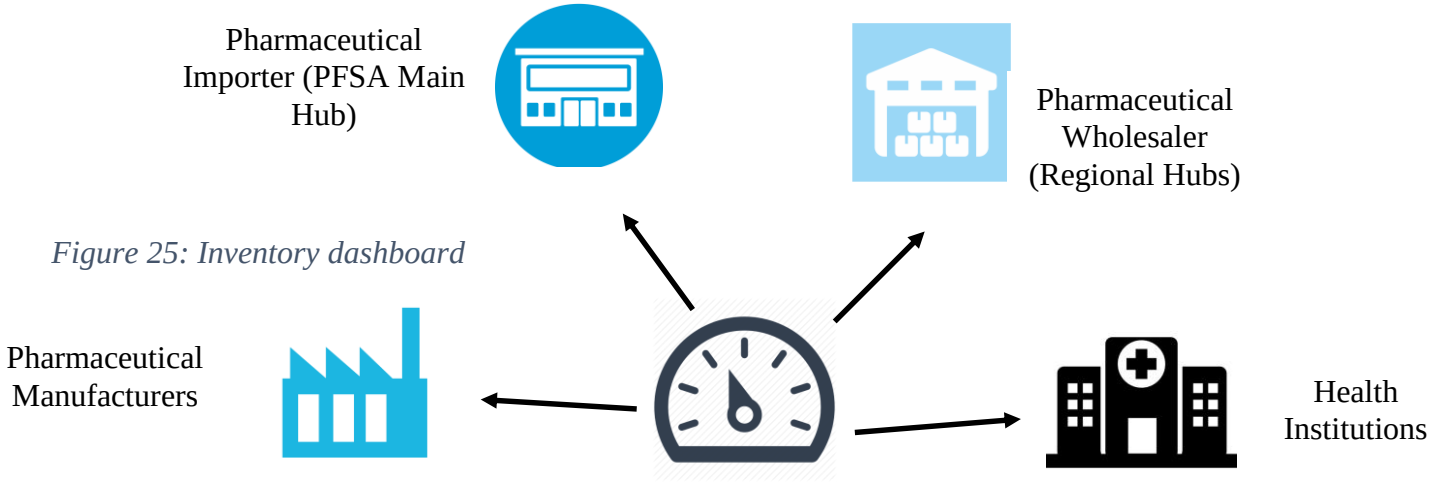


Figure 25: Inventory dashboard

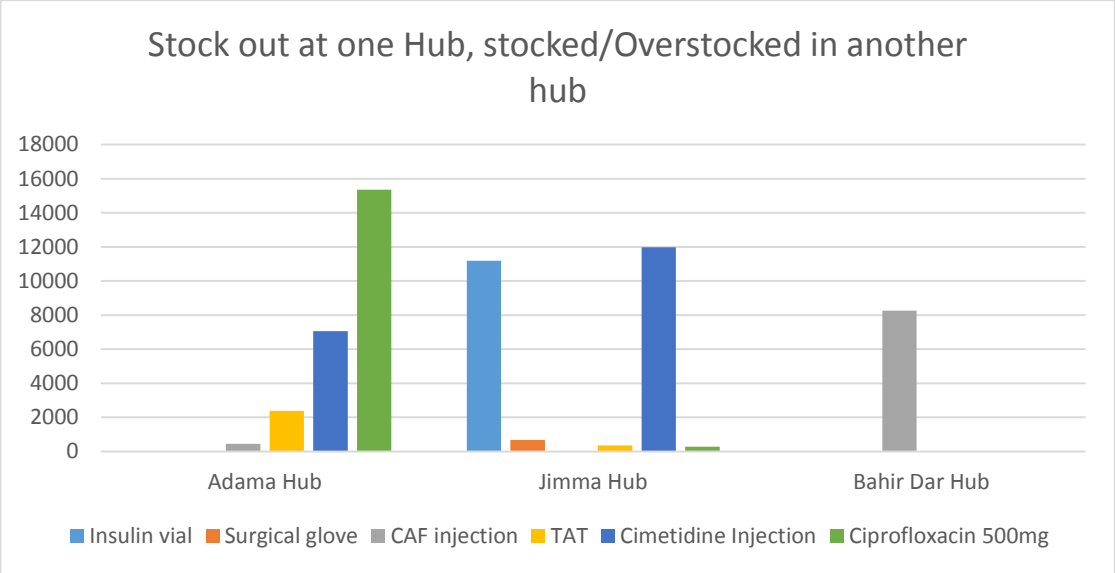


Figure 26: Poor stock distribution among regional hubs showing poor organizational proactive inventory decision making

From one project experience (blood supply chain dashboard development project),(Delen et al. 2011), predictive analytics capability could be integrated to the dashboard to yield significant benefits in inventory management, resource utilization and product distribution. In order to target two of the conflicting inventory management problems of this study: by maintaining enough inventories to meet planned demand but at the same time to minimize expirations and spoilage, the dashboard can be designed to summarize stock status and visually contrast excess and critical inventories being aided by a dynamic report which continually analyzes the inventories for products at each facilities based on their consumption rates and adopted inventory policy. Therefore from the inventory status analyses, it would become more appropriate to make forecasts of inventory and consumption in a better accuracy.

From the insight, it was found that the focal company is often involved in responding to emergencies and stock-outs. Mostly deviations of stock (stock-outs, overstock inventory) are detected and noticed only when the deviation causes a significant impact on the supply chain. To address such rising inventory management problems, we believe that, automated means of detecting these problems and bringing them to the attention of responsible focal company managers has a greater flexibility in the range of options to fix the issue. One way is by integrating the dashboard stock progress with various alert types (emails, sms) and notification mechanisms. Earlier communication of alerts (figure 28) of critical metrics such as inventory levels, not-in-stock items, unusual trends in consumption, expiration rates allow

supply chain managers to proactively identify problems and therefore develop solutions before the problems develop. This would change the reactive working system to proactive.

Alert Type	Issue Monitored	Algorithm, Heuristic, and/or Metric Used
Current Status	Excess and Shortage Inventories	(1) Number of days the inventories will cover based on historical consumption. (2) Number of days inventory will cover based on forecasted consumption.
Sudden Changes	Inventory, consumption, expiration and destruction spikes and valleys	(1) 2σ or 3σ deviation from respective mean. (2) % Deviation from respective mean. (3) % Deviation from previous spike or valley.
Trend Analyses	Gradual changes in inventory, consumption, expiration and destruction trends	(1) Consecutive X data points that are monotonically increasing (or decreasing). (2) X out of Y data points that are increasing (or decreasing). (3) % Increase (or decrease) of last data point compared to average increase (or decrease) over specified period.

Figure 27: A sample of main types of alerts from BRAMS project

The EPHCSS is a complex system with more than 3000 health institutions to serve all over the country. Responding to stock-out and overstocks requires visibility into not only the current inventory levels at a specific location but also the availability, proximity, and accessibility of inventory in all locations. In order to facilitate such rich visibility, the dashboard should also allow the integration of user interfaces like the GIS (Geographic based information system) – for a visual illustration of an optimized transportation plan and facility level inventory information.

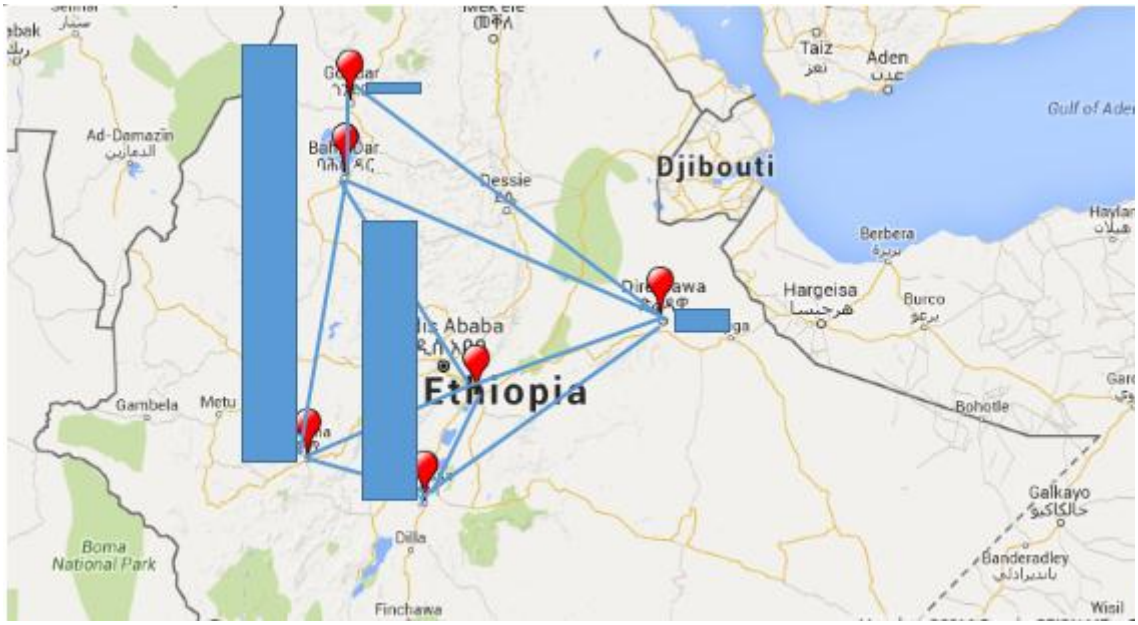


Figure 28: Balancing inventory network by supply chain optimization enabled with GIS and facility level inventory and transportation information

Source: Own work

As an example, the stock status of insulin injection (one of the most vital medications which needs to be 100% available) is reviewed with GIS integrated interface (figure 29), the bars show the amount of stock in inventory at the sampled PFSA hubs (Current inventory data taken from part-I of this study) and the connecting lines proposing efficient ways of transportation plan for moving the products around the network to meet the shortages and excess inventories at various locations.

3.3.3 Section III: Supply chain visibility solution scorecard

Supply chain visibility projects get off-track because they focus on functionality as a benefit in itself. This is not an accurate understanding of why visibility adds value. Features of a visibility system or process are only valuable to the degree that they fit into the targeted business decision, (McIntire 2014).

As an example, if a visibility process delivers beautiful visualizations of the meta-data, such as by plotting flows of materials on to a map, this is an interesting feature. But if the targeted business decisions don't have use for the feature, then it's not going to add value to the company. Therefore in this supply chain visibility solution scorecard, the degree to which a visibility process meets the targeted business needs of the decision making process and the output offered by the visibility process, fitness, is measured.

On the high end is a 100% fitness, where the visibility solution literally fully automates the decision at or above levels possible by a human being. At the other end is zero percent fitness, where the system adds nothing meaningful to the decision-making process.

In this visibility solution scorecard, first to calculate fitness percent score, a four metric are graded with scales (annex 8.0) to assign a score to each metric and each targeted business decision, then the scores summed and divided by 24(the total sum value of all grade scales).

Second, the cost metric came in to play so as to compare visibility fitness across two options. The fitness percentage for each option is plotted against cost in an efficiency frontier.

Visibility Solution Name: **GS1 data matrix barcoding + GDSN + Inventory Dashboard**

Targeted **Business Decisions** which the visibility solution should support	Sensitivity	Accessibility	Intelligence	Decision Relevance	Fit %
Inventory Management (IM)					
Annual Demand Quantification	1	3	0	1	20.8%
Analysis/Evaluation/Aggregation of APR	1	3	0	1	20.8%
Final Analysis (VEN/ABC analysis)	1	3	0	1	20.8%
Quantification/Rationing	2	3	0	1	25%
Analysis/Rationing	2	3	0	1	25%
Stock request process	3	3	4	2	50%
Counterfeit detection (CO)					
Selection of supplier	0				0%
Delivery and Receive authorization	4	4	3	5	66.6 %
Tracing (Tr)	4	4	3	2	54.1 %
Manufacturer delivery inform. Record					
Actors receive inform. Record					
Actors issue inform. Record					

Table 11: GS1 data matrix solution visibility score-carding fitness score

Estimated Total Cost: __10,000 Euro[3]____ Overall fit %: ___35.38%____

Visibility Solution Name: **GS1 RFID with passive tag + EPCIS + Inventory Dashboard**

Targeted **Business Decisions** which the visibility solution should support	Sensitivity	Accessibility	Intelligence	Decision Relevance	Fit %
Inventory Management (IM)					
Annual Demand Quantification	1	3	0	1	20.8%
Analysis/Evaluation/Aggregation of APR	1	3	0	1	20.8%
Final Analysis (VEN/ABC analysis)	1	3	0	1	20.8%
Quantification/Rationing	2	3	0	1	25%
Analysis/Rationing	2	3	0	1	25%
Stock request process	3	3	4	2	50%
Counterfeit detection (CO)					
Selection of supplier	0				0%
Delivery and Receive authorization	4	6	4	5	79.16%
Tracing (Tr)	4	6	4	2	66.67%
Manufacturer delivery inform. Record					
Actors receive inform. Record					
Actors issue inform. Record					

Table 12: GS1 RFID solution visibility score-carding fitness score

Estimated Total Cost: ___100,000Euro[1]____ Overall fit %: ____38.52 %_____

[3] Estimate is taken from : an amount of another case study (considering direct operating cost and fixed asset cost) and a simple rough estimation (annex 10.3)

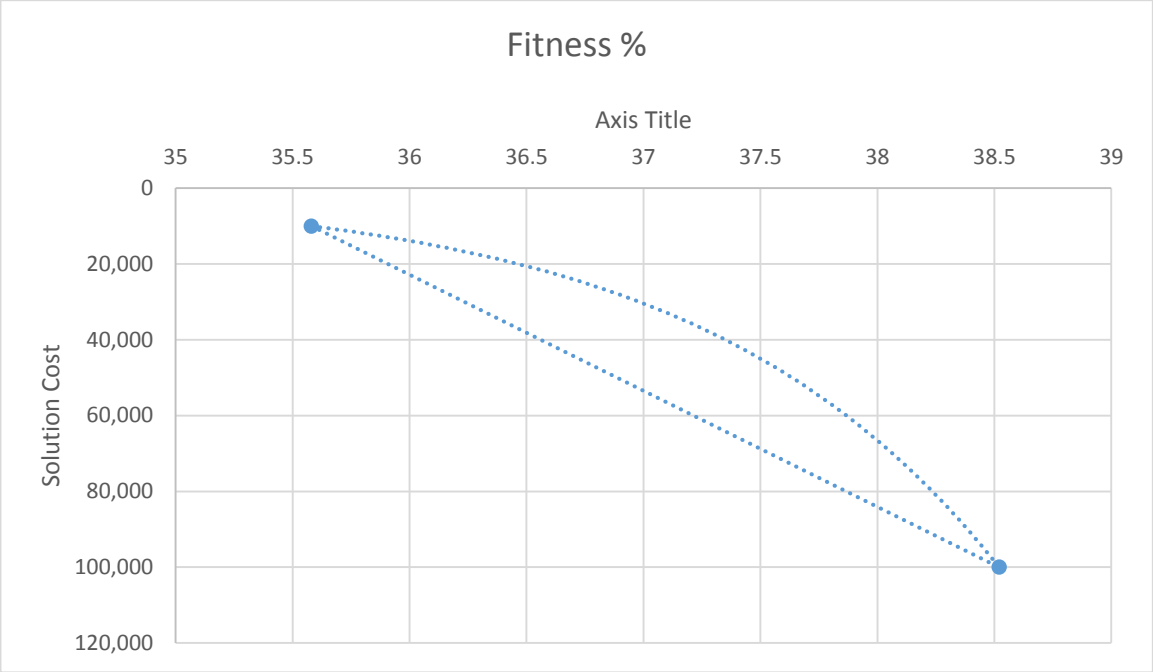


Figure 29: The efficiency frontier for the two solutions

Obviously it is of limited use to compare high and low cost options in terms of cost alone. But the efficiency frontier gives us a simple and visual display of trade-offs which occur between cost and visibility fitness .The dashed line on figure 30 above shows the efficiency frontier. Because only two solutions are compared, the frontier may look a bit tricky to compare. With a very high increase in investment, the fitness percentage hasn't increased as much from barcode to RFID.

Therefore it is recommendable to consider the GS1 data matrix from this point of view. Other similar implementation case studies mention that the return on investment for RFID is still ambiguous and unclear(Poirier and McCollum 2006, Bendavid et al. 2012). But the management can still consider to study other solutions within the frontier (ERP, VMI) in further researches to comparatively visualize the impact their fitness's have with regards to the initial investment with respect to GS1 and RFID.

We believe that with the current recommended approaches, the health system could go one step ahead against the current targeted problems, but it would be costly to do if product coding is done only by few of the manufacturers, and those few manufacturers may become reluctant to participate. Therefore further actions requires the government's interference to enforce all manufacturers to implement the system countrywide.

4.0 Summary, conclusion and recommendation for further research

My work experience combined with my academic studies and personal relationship with professors at Molde University College, became my motivation to conduct this research study.

Supply chain challenges like poor inventory management, inefficient tracking and tracing, fake or sub-standard medicines are of concern for the health supply chain of Ethiopia posing a major health risk. There are so far very few scientific studies conducted which focused specifically on PFSA supply chain challenges. The ones that exists are informal and non-recent.

To find out where the challenges outlined focusing on PFSA, analysis one of collected performance indicators gives an indication of the supply chain performance within EPHCSS.

The supply chain performance indicators from this study asserts the empirically observed existence of the challenges within PFSA. Product availability survey within regional hubs show, vital products availability ranges as low as 65% to 84.4%, a figure against a 100% availability in the service level agreement by the agency. Of the selected vital products, 75% of the commodities experienced stock-out for 1 to 4 times within the past 6 months of time for a duration of 10 to 147 days. Only 16-50% of the products were stocked correctly where understocking being very likely. Implication of the forecast accuracy error of (0.22, 0.25 and 2.59) gives an indication that poor forecasting probably is one factor towards inefficient product availability for the sampled products within the measuring period. The non-practicability of electronic ordering system from focal company to suppliers (considering the non-electronic ordering system increases the lead time) and an occasional (monthly) stock status monitoring of focal companies to regional hubs were also other issues we considered that might be negatively affecting the supply chain performances.

Supply chain visibility is rated as the most important measure to improving supply chain performance both by business leaders and researchers. It improves company performance by supporting the decision making processes. Therefore, this became the initiative to look at supply chain visibility implementation in particular at EPHCSS.

More than 75% of the information flows that are exchanged within suppliers and health institutions is accessed by PFSA. However, the outbound and inbound supply chain visibility is poor from the quality aspect where freshness is below 2 and accuracy between 2.5 and 3(of the maximum value of 4). The implication of the values is that: the focal company is not accessing/visualizing in real-time key information like stock-status and trend of health institutions inventory data which eventually would make decision making inefficient and responses more of reactive.

Lastly, by enabling the focal company with approaches which could improve information sharing along the chain, data visibility could be enhanced which could ultimately empower an informed decision making process and proactive measures so as to improve the supply chain performance of the system and combat the key research challenges identified.

GS1 data matrix barcoding with a unique serialization integrated with an inventory dashboard within EPHCSS is one cost efficient approach (with respect to the budget of the ministry of health) which enables to easily track and trace products movement and offer data visibility as fresh and accurate as possible. Accurate, fresh and data rich inventory dashboard would enable decision makers to have a proactive approach therefore would trigger a better stock management. A unique serialization of products and an authorization at the time of receive and issue would block most of the possible ways of counterfeited and unauthorized medicines inflow to the legitimate supply chain.

In conclusion, the study confirmed for the samples studied under the measuring period, that product availability within the focal company is not as per the service level agreement signed by the agency. Most hubs are not stocked according to the IPLS recommended policy of stocking. The responsible management body should therefore take this urgent issue of product availability and other results of supply chain indicators to consideration for appropriate measures. The outbound and inbound supply chain visibility index is better in the amount of information accessed by the focal company but the accuracy and freshness of access is found out to be poor. Therefore, diagnostic measures on the quality of data visibility should be taken. Conducting similar further studies to find out which practices or why the program supply line experiences have a relatively

better visibility values over the RDF supply line is advisable. In addition, to have a more detailed insight about the impacts of the recommended visibility approaches: we recommend a pilot study.

5.0 Research limitations;

In part-I, identification of the kind of information flow and categorizing them under each of the information categories was a bit tricky.

Not finding any quantitative supply chain visibility studies on similar systems limits benchmarking.

Grading of the target decisions with respect to sensitivity, accessibility, intelligence and decision relevance was very ambiguous to decide while score-carding the visibility solutions.

The supply chain measurement is limited interms of the number of pharmaceuticals included and the number of indicators selected.

6.0 Annexes

Annex 6.1 Detail personal observation of challenges at PFSA

Spots from around the warehouse;

- Products, which required a cold room storage condition, were most of the time being kept in a pseudo cold-room, which was not working most of the seasons (The temperature reading of the in-house built cold room was most of the time well above 8^{o}c- due to technical failures or power shortages). The only kind of management that was applied by the hub until the in-house cold room is fixed was usage of cold boxes all around product packages in an assumption to lower the surrounding temperature. However, in reality, the ability of this technique to lower the temperature; was not more than a myth. It did not go well above moistening the packages.

- As pharmaceuticals are very sensitive kind of commodities, they have and require their own standard of space requirement. The expanding stock demand from lower level institutions required carrying of higher amount of stock but with the same storage spaces. Due to the shortage of enough space, there were many episodes where pharmaceuticals were kept one over the other.

Spots from the angle of Inventory Management;

- Every year the hub ends up with thousands SKU's of products and with tens of product varieties *expired and disposed*. (E.g. Worth more than 1 Million USD per year burned in expired drugs in 2015 from Jimma Hub)
- Every year the hub ends up with thousands SKU's of products and with tens of product varieties *over stocked*. (E.g. IV fluids hold more than 20% of the warehouse space-in most of the year)
- Throughout the year, there were frequent, long period duration *Stock-outs* of vital, essential and non-essential products within health facilities and the hub itself. (In 2012, cross country expiry and stock out of two drugs from anti-TB treatment regimen was recorded for approximately 1 month and other repeated cases posing a huge health threat.)
- There were many episodes where, the number of products physical count in the warehouse and the *count on the stock* card/bin-card/electronic system-HCMIS did not match.
- There were reports of products with high price value, which were *missing* from the warehouse.

- Untimely segregation of expired / damaged products from the normal ones.

Spots from the angle of Distribution Management;

- *Re-calling* of products (due to quality problem) was very tedious and difficult to locate within a short period. As in most cases, *similarity of batch* number on the invoice/STV and the product leaving the warehouse is not a necessity making the issue a big problem. (E.g. Codeine Phosphate preparation with life threatening risk is recalled at the end of 2015 by a local manufacturer (APF). The recollection process was very sluggish.)
- Swinging demand flow from facilities made the quantification and forecasting of stock at hub level a difficult job.
- Reports of Pharmaceuticals being *diverted* or the legitimate ones being replaced with *fake ones* from the distribution line, PFSA to Facilities. (E.g. Cases of theft report for *Co-artem* is quite common (a drug to treat Malaria-one of the many, but frequent) from the legitimate supply chain by professionals and non-professionals along the line.)
- *Missed products* or *missed facilities* from the list of products to have been delivered or facilities to have been supplied while on delivery.
- *Miscommunication of supply reporting* submissions between health institutions, PFSA and Regional Hubs.
- Frequent facility *emergency stock requests* disturbing the hubs stock balance and adding an extra resupply transportation costs.
- Shortage of ready-to-go distribution vehicles at the time of the distribution week.
- *Un-proper management of storage conditions* of 'cold room' products during delivery; there were no cold-room equipped vehicles for the hub. Products, which required a cold room temperature, were managed by keeping them in a cold-room box, staffed with cold bags. The vehicles cross more than 500Kms, reaching extremity facilities, taking them more than three days, through sunny and humid atmosphere without even changing the cold bags of the cold boxes.

Annex 6.2 Supply chain visibility enhancing solutions

Product visibility in the supply chain is achieved and improved by tracking and tracing a product, possibly throughout its lifecycle, using a variety of methods and technologies like barcode, RFID, communication channels and sensor technologies, (Musa, Gunasekaran, and Yusuf 2014).

Barcodes

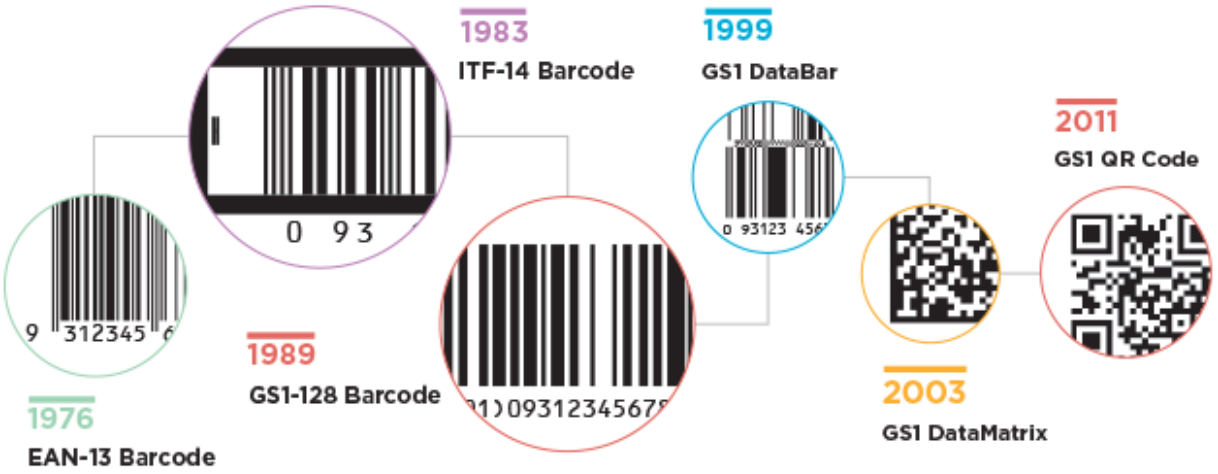


Figure 30: the different kinds of barcodes with their historical dating

The barcode is an optical and machine-readable technology for representing data relating to the object to which it is attached. The barcode was first used commercially in 1966, but the very first scanning of the Universal Product Code (UPC) barcode was in June 1974. The very common use of barcodes is its application. In point-of-sale (POS) management, providing a detailed, accurate and current information on sales, thereby accelerates decisions concerning inventory management. The two drawbacks of the barcode are that it is a read-only technology – meaning that once printed, the data cannot be changed – and the scanner needs a relatively short direct line of sight to the barcode. There are two types of bar-codes: Linear (or 1D) and 2D. Linear barcodes represent data by varying the widths and spacing of parallel lines. There are many types of 1D barcodes, some of them are; Code 39, Code 93, Code 128, Coda-bar, International Article Number (EAN), UPC-A, UPC-E, DataBar-14, Interleaved 2-of-5, HIBC (Health Information Barcode), Quick Response barcodes (QR codes), PZN (Germany), IMH (Italy), MSI, GS1 Data-Bar Expanded, GS1 Data-Matrix), publishing barcodes (ISBN, ISSN, ISMN). 2D barcodes are those which encode significantly more data and use rectangles, dots, hexagons and other geometric patterns in two dimensions to represent data. Among the most popular 2D barcodes are Data Matrix, PDF417, Micro PDF417, and 2D Pharma.

RFID

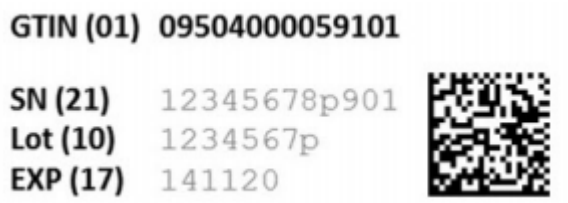
RFID provides an alternative means to product identification. The main elements of an RFID system are the interrogator (or reader), the transponder (or the tag), and the middleware that collects and filters data from the reader before the data is transmitted to enterprise applications and information system. The reader and the tag do not require a direct line of sight for communication like the barcodes. Some RFID tags offer additional write memory that could serve as storage for application data such as the expiry date or date of manufacture, to facilitate data exchange where there is no network coverage. The cost of RFID chips remains very high and actually is prohibitive for many uses. There are two types of RFID tags, passive ones which are the simplest and cheapest types that doesn't have an onboard power source therefore wait for a signal from an RFID reader. They work by relying on the very high-power energy transmitted by the reader while the active tags are equipped with an onboard power source therefore could automatically broadcast their signal.

GS1 standardization

GS1 system is a set of standards that through its implementations, facilitates an efficient supply chain worldwide due to uniquely identified products, logistic units and locations. These standards are intended to be global, neutral, and non-ambiguous. They facilitate product and data flow between supply chain partners such as suppliers, manufacturers, wholesalers, logistic providers, transporters, hospitals. They help automatic data capture and data management, increase data flow, reduce cost and secure the supply chain. There are three key components offered by GS1: Identification of a product with unique and global codes of different information and purpose, capturing of data from products tagged with barcodes or RFID and sharing of the master/transactional/event data captured along the network or common framework.(GS1 July 2015)

Figure 31: The GS1 system of records

There are different policies followed for product marking in GS1. HRI (human readable interpretation) information printed adjacent to a barcode or RFID tag represents data carried in the barcode or tag (figure 11). When marking healthcare products, GS1 identification keys are used to identify trade items and logistic units. Additional data may be associated with the GS1 identification keys through the use of GS1 application identifiers (AI's). The following four are the common data included while using the 2D data matrix which is the commonly used type of GS1 barcode for tagging health care products;



Source:(GS1 July 2015)

Figure 32: HRI text with GS1 Data matrix label

GTIN, AI (01)-This is a key for a unique product identification used to identify trade items.

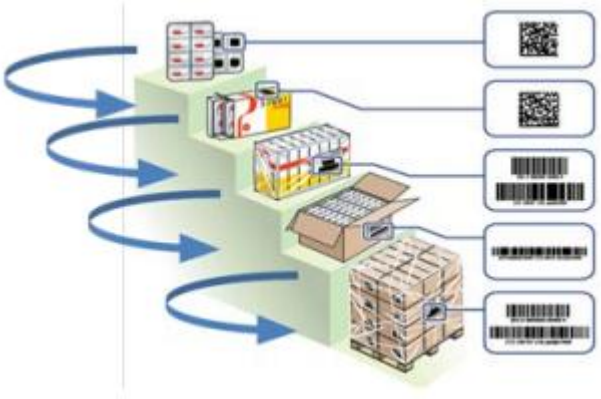
Batch/Lot-AI (10)-When additional data is required to identify batch number, this identifier is used and typically is assigned at the point of manufacture. This additional data is alphanumeric with a variable length of up to 20 characters.

Expiration Date –AI (17)-When additional data is required to identify expiration date, this identifier is used.

Serial Number-AI (21) **–**If health care products are to be individually tracked and traced using a serial number, this application identifier is used. This additional data is alphanumeric with a variable length of up to 20 characters.

When adopting the GS1 standards for healthcare, product marking consideration is given to marking levels, product configuration, package hierarchy and distribution channel. The marking hierarchy range from direct part mark, primary package, secondary packaging, case/shipper and pallet (figure 12). The marking levels range from minimum level providing a GTIN with no attribute information, enhanced level providing GTIN plus batch number and expiration date for products that require a higher level of traceability control and highest level providing GTIN with serial number and expiration date for products that require the highest level of traceability control.

Figure 33: Package marking hierarchy illustration



Source:(GS1 July 2015)

ERP

Of the different systems available that allow internal organizational information visibility is the ERP system, a software architecture which identifies and plans the resources needed to take, make, ship and account for customer orders facilitating the flow of information among the different functions within an enterprise. At the core of this enterprise software is a central database, which draws data from and feeds data into modular applications that operate on a common computing platform, thus standardizing business processes and data definitions into a unified environment. By this way, the system provides consistency and visibility or transparency across the entire enterprise. A primary benefit of ERP is easier access to reliable, integrated information. A related

benefit is the elimination of redundant data and the rationalization of processes, which result in substantial cost savings.

mPedigree

Being developed by a Ghanaian engineer, Mpedigree is another platform which enabled information sharing and visibility for the actors within a supply chain. Established mainly to help people affected with counterfeit medicines, (mPedigree 2016) Mpedigree applies the use of mobile and web technologies in securing products against faking, counterfeiting and diversion. The technology platform made it practical where scratchable codes are printed on medicine packets which later are scratched and sent to a number by the patient or health professional as an authorization before making the medicine for use.

QR/CRP/VMI

Quick Response (QR) was born in the beginning of the 80s in order to reduce delay needed to serve the customer in the textile industry. The supplier receives a point of sale data from the customer and uses this information to synchronize its production. In the beginning of the 90s the Continuous Replenishment Policy (CRP) was developed: based on consumer demand, the CRP pull system replaces the historical push systems. Gradually, the sphere of decision of the suppliers is growing until the VMI transfers the totality of the customer's inventory replenishment responsibility to the supplier, (Yao, Yuliang, and Dresner 2008, Marqués et al. 2010.)

Annex 6.3 Information systems in EPHCSS

HMIS (The Health Management Information System)

The Ethiopian Health Management Information System (HMIS) has been implemented since 2008 to capture and provide core monitor-able indicators used to improve the provision of health services, and ultimately, to improve health status of the population. Since then, the health sector has been showing achievements in planning, budgeting, decentralization, review of plans and progress, involvement of partners and utilizing information in decision-making. HMIS is a major source of information for monitoring and adjusting policy implementation and resource use. At the end of 2013, 122 (98%) public hospitals and 2697 (87%) health centers implemented HMIS.

HCMIS (Health Commodities Management Information System) (PROJECT 2010)

HCMIS is a warehouse and facility management system developed by the USAID | PROJECT (Deliver and SCMS) for use in the Ethiopian Ministry of Health and the Pharmaceutical Fund & Supply Agency (PFSA) to support the country's pharmaceutical logistics management system. The development was initially written for hospitals and high traffic health centers, when it was first started in 2008. In 2010, the features were extended to include a warehouse module to support PFSA's hub warehouses. Though both the facility and hub application are developed and maintained jointly, they separately referred as HCMIS Facility Edition (HCMIS FE) and HCMIS Hub Edition (HCMIS HE). The HCMIS Hub Edition often referred to as only HCMIS is a record-keeping system to manage daily transactions. Moreover, provides a mechanism by which essential and standard working procedures can be enforced in these pharmaceutical settings. Some of the standards supported by the system are First to Expire, First-Out (FEFO), batch, and expiry tracking. HCMIS is designed to help managers at warehouses and/or facilities to generate appropriate and timely stock reports that help them make sound decisions.

Annex 6.4 Roles and responsibilities of actors in EPHCSS

Table 13: Roles and Responsibilities of PFSA

1	Forecast national pharmaceuticals need based on the demand of Health Facilities.
2	Procure and store pharmaceuticals.
3	Determine stock levels.
4	Receive reports and orders from health facilities and distribute pharmaceuticals to health facilities
5	Maintain stock records and monitor stock status.
6	Build the capacity of health facilities in the areas of pharmaceuticals supply management and rational pharmaceuticals use through provision of technical and material support.
7	Exchange information with FMOH and Regional Health Bureaus (RHBs) regarding the supply and use of pharmaceuticals.
8	Coordinate and lead partners working on supply management and rational pharmaceuticals use.
9	Undertake supportive supervision in health facilities in collaboration with relevant stakeholders
10	Develop data recording, requisition and reporting formats.
11	Monitor and evaluate the performance of the logistics system.
12	Improve facility store management in collaboration with the ministry and partners.

Annex 6.5 IPLS (Integrated Pharmaceutical Logistic System)

IPLS is the term applied to the single pharmaceuticals reporting and distribution system based on the overall mandate and scope of PFSA. It was first implemented in 2010 to integrate the supply management of Program pharmaceuticals and later RDF ones- aiming to ensure that patients always get pharmaceuticals they need and those included on the national pharmaceuticals procurement list (NPPL). The long-term plan is direct delivery of all pharmaceuticals in an integrated manner to all public health facilities every two months based on demand.

At each level, the system provides accurate and timely data for decision-making where product related information flows up from health facilities to the agency whereas products flow from the Agency down to health facilities every two months (figure 7). Routine monitoring reports show that IPLS is improving information recording and reporting, storage and distribution systems, as well as the availability of essential commodities at service delivery points (SDPs).

The mechanisms of reporting and supply pattern are different in each of the categories though; Program and RDF.

Program pharmaceuticals reporting and supply

The reporting for order of Program pharmaceuticals is every two months by hospitals and health centers and the delivery/supply by PFSA to these facilities could be directly or indirectly.

Direct delivery sites are facilities that receive program pharmaceuticals directly from PFSA hubs whereas non-direct delivery sites are health centers that receive products from PFSA hubs through Woreda Health Offices (WoHOs). Health centers and hospitals under direct delivery complete a report and requisition format and send it to PFSA Hubs for requisition processing. Whereas, WoHO's complete a report and requisition format for non-direct delivery facilities and send it to PFSA branches. The collection and reporting of a Logistics information is every other month by health centers and hospitals on logistics management information system (LMIS) forms.

A copy of the health centre report and order and a copy of each health post report are sent to the Woreda Health Office for management and supervision purposes. A copy of the hospital report

and order is sent to the Regional Health Bureau for management and supervision purposes. The overall information system includes a mechanism for providing ―feedback to lower level facilities from upper level facilities. In the feedback reports, facilities will be able to see how they are performing compared to other facilities in their area and will be able to facilitate stock transfer.

Figure below illustrates the overall flow of program pharmaceuticals and information in the IPLS.

RDF pharmaceuticals requisition and supply

Health centers and hospitals complete RRF (Report and Requisition Format) as per the facilities review period, which can be every two-month, every quarter or every six months and purchases products from affiliated PFSA branch.

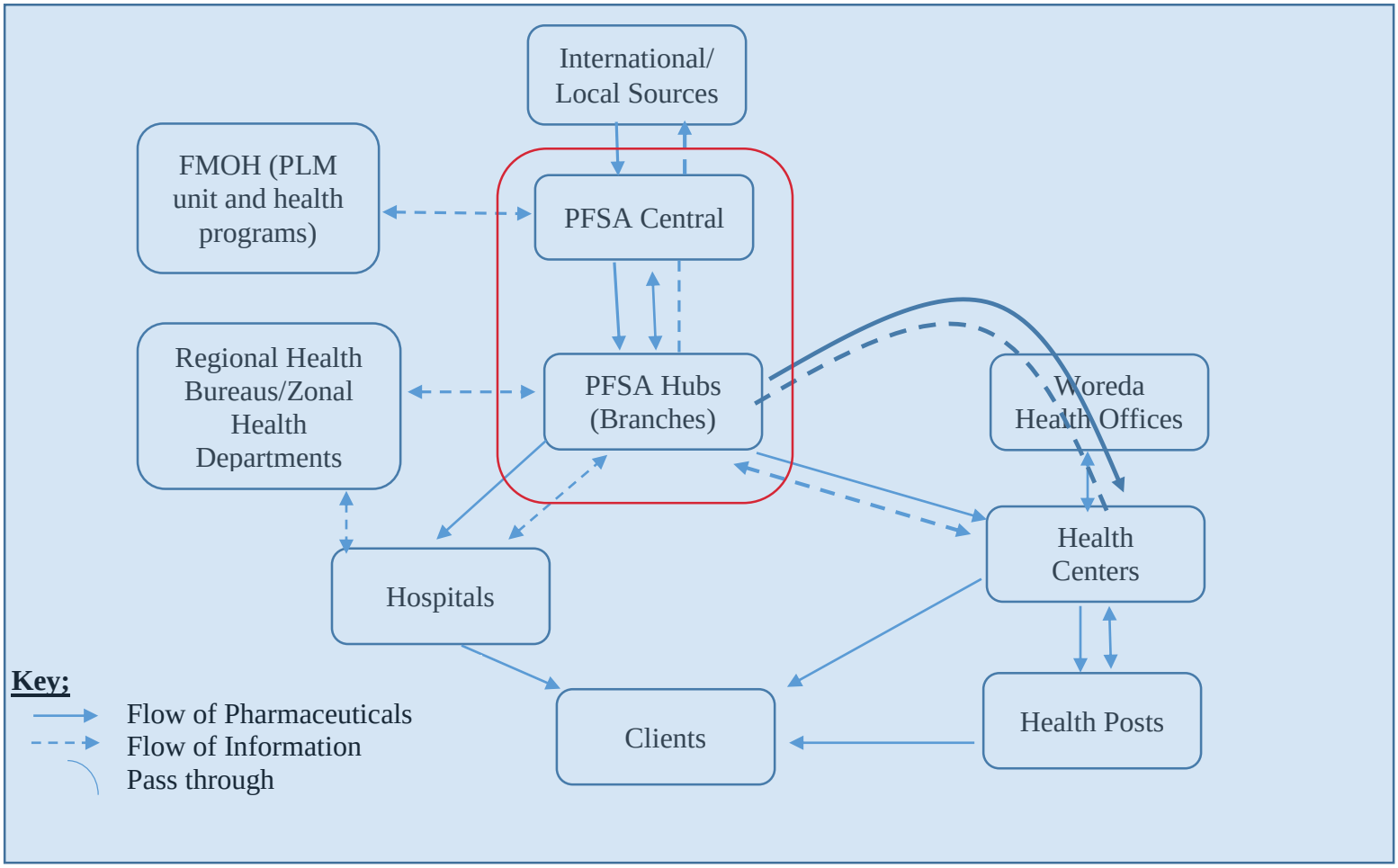


Figure 34: Overview of pharmaceuticals and information flow in IPLS

Source; Own work

Annex 6.6 Supply chain performance indicators description

Methodology one

The methodology is organized by supply chain/logistics functions categorized in four: Product Selection/Forecasting/Procurement, Sourcing, Warehousing/Storage, Inventory Management/Logistics Management Information/System/Customer Response and Distribution/Transport. Each one of these supply chain/logistics functions is then further divided by four type of indicators: quality, time, financial, and productivity which are adapted and integrated- which is the core point behind this metrics giving it a holistic approach of measurement

Quality: These indicators are often the simplest to implement and measure. Typically, they tell how well the company is performing a specific activity—a common logistics indicator in this classification is accuracy— including forecast accuracy error, inventory accuracy, picking accuracy, etc.

Time: These indicators focus on the time it takes to complete specific activities. They show whether saving time during specific activities can improve the overall supply chain performance.

Financial: These indicators identify the supply chain cost drivers .

Productivity: These indicators examine how well resources are used. For example, filling vehicles to their capacity, instead of sending out vehicles half-full, could reduce costs and improve efficiency.

Methodology two

The visibility measure has been developed on the basis of the following basic principles:
(1) Methodological accuracy. The rigorousity of the output from a scientific point of view.
(2) Usability. The ease of the model application to real companies

(3) Diagnostic support. The model also provided the insight of knowing and helping the user identify where visibility should be improved and how this can be achieved.

The model has components which guided this study throughout;

1. The main types of information which can be exchanged across the supply chain were classified based on the following assumptions and under the following classes.

- **Transactions/events**: Information that has to be communicated when an event takes place (e.g. order confirmation, order modification, advanced shipping notice, payment notice and sales reporting).
- **Status information:** Information that describes the status of some resources or of a process (e.g. order status, stock level, sent orders, stocking capacity, residual shelf-life, work-in-progress, backlog, machine saturation and production residual capacity).
- **Master data:** Information linked to the features of products (e.g. basic technical features, extended technical features, commercial information, residual product life-cycle, bill of materials, managerial product information and stock keeping unit features).
- **Operational plans:** Information about the company's future plans (e.g. distribution plan, production plan, strategic sales forecast, operational sales forecast and promotions plan).

2. A set of metrics and a measurement model were applied and used to assess the level of supply chain visibility quantitatively, globally, partially from the angle of defining the most important features of information flows to be considered in the analysis (e.g. quantity, accuracy, speed or freshness);both from the quantity and quality aspect.

Instrumental steps and ranking tables for methodology two (Source: (Caridi et al. 2010a)

Table 14: The scale to judge the quantity of the exchanged information

Score	Description
1	The focal company has access to none or little (less than 25 per cent) of the information within the analysed category (transactions/events, status information, master data and operational plans)
2	The focal company has partial access (between 25 and 50 per cent) to the information within the analysed category (transactions/events, status information, master data and operational plans)
3	The focal company has access to a fairly good amount (between 50 and 75 per cent) of the information within the analysed category (transactions/events, status information, master data and operational plans)
4	The focal company has access to a large part (more than 75 per cent) of the information within the analysed category (transactions/events, status information, master data and operational plans)

Table 15: The scale to judge the accuracy of the exchanged information

Score	Description
1	The accuracy of the exchanged information within the analysed category (transactions/ events, status information, master data and operational plans) is usually very low and unsatisfactory
2	The accuracy of the exchanged information within the analysed category (transactions/ events, status information, master data and operational plans) is usually satisfactory, but situations in which the information is incorrect are not uncommon
3	The accuracy of the exchanged information within the analysed category (transactions/ events, status information, master data and operational plans) is usually satisfactory, and the information is incorrect only in a few situations
4	The accuracy of the exchanged information within the analysed category (transactions/ events, status information, master data and operational plans) is always satisfactory (very good accuracy)

Table V.
The scale to judge the freshness of exchanged information

Score	Transactions/events	Status information	Master data	Operational plans
1	Less than once a day	Unsatisfactory	Monthly or less than once a month	Not visible at all
2	Daily frequency	Information is updated only when the node is asked to provide data	Weekly or fortnightly frequency	Information is updated only when the node is asked to provide data
3	Few hours of delay	In some cases information is updated only when the node is asked to provide data	Daily frequency	Plans are visible in real time, but changes are visible only when the node is asked to provide data
4	Real time	Real time	Real time	Plans and their changes are visible in real time

Partial visibility with respect to the nodes (suppliers and hospitals), and with respect to the information types is then calculated mathematically by applying the formulas.

Node_Visibility_Quantity/Accuracy/Freshness of the focal company =

$$\sqrt[4]{\begin{array}{c}(Quantity/Accuracy/Freshness\ accessed\ of\ status\ information \\ x\ Quantity/Accuracy/Freshness\ accessed\ of\ \frac{Transaction}{events}\ information \\ x\ Quantity/Accuracy/Freshness\ accessed\ of\ Master\ Data \\ x\ Quantity/Accuracy/Freshness\ accessed\ of\ operational\ data \\ )\end{array}}$$

Overall_Visibility_of_Status /transaction/master/operational information of the focal company=

$$\sqrt[3]{\begin{array}{l}(Quantity\ accessed\ of\ Status/transaction/master/operational\ \ information \\ \quad x\ Accuracy\ of\ status/transaction/master/operational\ information \\ \quad x\ Freshness\ of\ status/transaction/master/operational\ information\ )\end{array}}$$

An overall measure of the supply chain visibility is obtained by combining the measures of visibility of the supply chain nodes. The contribution of each node to the overall measure is weighted on the basis of criterias/parameters:

Parameter 1; ***Localization in the supply chain(neighborhood),*** i.e. the distance of each node from the supply chain leader both in terms of the number of tiers between the node and the focal company and in terms of its vertical integration;

The main idea is that visibility of "near" nodes (e.g. first-tier suppliers) is much more critical to the focal company than visibility of "distant" nodes (e.g. second or third tier suppliers), because their operations are much more tightly connected to those of the focal company. The nearer the node is to the focal company, the higher is its relevance (i.e. its weight).

The localization weight ***wlock,*** assigned to a generic node, ***k,*** is calculated as;

$$\mathrm{wloc}_k = \begin{cases} 1 & \text{for first-tier suppliers} \\ 1 - \frac{\sum_{n \in I_k} \mathrm{AV}_n}{S_{m,\mathrm{FC}}} & \text{for suppliers belonging to tier } z, \text{ with } z \geq 2 \end{cases}$$

where:

- I_k is the set of nodes belonging to the path from k to the focal company.
- n is a node belonging to I_k.
- AV_n is the added value of the node n.
- m is the first-tier node belonging to I_k.
- $S_{m,\mathrm{FC}}$ is the volume of sales from the node m to the focal company FC.

Parameter 2: ***Significance in terms of value of the goods supplied:***

The more the focal company buys from a supplier, the more interested the focal company should be in having visibility of this supplier. So, a higher weight assigned to suppliers who provide significant amounts of the overall purchases.

For the first-tier nodes, the significance weight, ***wsigk***, is calculated as follows:

$$\mathrm{wsig}_k = \frac{S_{k,\mathrm{FC}}}{\sum_{n \in Z_1} S_{n,\mathrm{FC}}},$$

, where n belongs to the set of first tier-nodes, Z1.

Parameter 3: ***Criticality measured using a qualitative scale based on the Kraljic matrix.***

A four response scale drafted from Kraljix matrix is used to measure the criticality of a supply chain node. The scale combined two characteristics:

- The impact on profits and
- The supply risk.

Table 17: Qualitative judgments on the exchanged information criticality

Score	Description
1	The component is not critical (from a strategic perspective) for the finished product (e.g. it can be easily substituted), and there are several suppliers from which it can be obtained
2	The component is critical (from a strategic perspective) for the finished product, but there are several suppliers from which it can be obtained
3	The component is not critical (from a strategic perspective) for the finished product, but there are few suppliers (or only one) from which it can be obtained
4	The component is critical (from a strategic perspective) for the finished product and there are few suppliers (or only one) from which it can be obtained

Assigning a weight to the nodes:

The weight of a generic node, k, in the inbound supply chain of the focal company is calculated based on the assumption that nodes are not included in the analysis if;

- They are "distant" from the focal company (***low wloc***),
- The amount of exchanged goods is not significant (***low wsig***),
- They are not critical in terms of supply risk, according to Kraljic (***low criticality***).

The threshold W * used to consider the trade-off between the accuracy of the visibility measure and the cost of the measure, which both grow with the number of nodes considered into the model. The weights of the nodes are then normalized (Wstd, k) so that their sum is one.

Table 18: The computation of the weight of the node

	Localisation and significance	
	Low ($\sqrt{\text{wloc} \cdot \text{wsig}} < W^*$)	High ($\sqrt{\text{wloc} \cdot \text{wsig}} \geq W^*$)
Criticality		
Low (score: 1, 2)	0	$\sqrt{\text{wloc} \cdot \text{wsig}}$
High (score: 3, 4)	$\sqrt{\text{wloc} \cdot \text{wsig}}$	$\sqrt{\text{wloc} \cdot \text{wsig}}$

A global measure of visibility: A global measure of the supply chain visibility is then obtained as a weighted average of the judgements of visibility of each node. Where N is the number of nodes of the inbound supply chain.

$$\text{Supply chain\_overall\_visibility} = \sum_{k=1}^{N} (\text{Node\_overall\_visibility}_k \cdot W_{\text{std},k}),$$

Methodology three

The approach bases on the fact that, visibility solution must be interruptive, resulting in a different— and better— business decision. Otherwise, with no value created by visibility. It also justifies in a way, the only two ways a decision can be improved by supply chain visibility solution: if only the solution is able to

- Improve the information available to the decision mechanism (faster, more accurate, more complete, and so on)
- Improve the decision making mechanics itself (change the individual or group who makes it, change the criteria, change the frequency, enforce consistency, and so on)

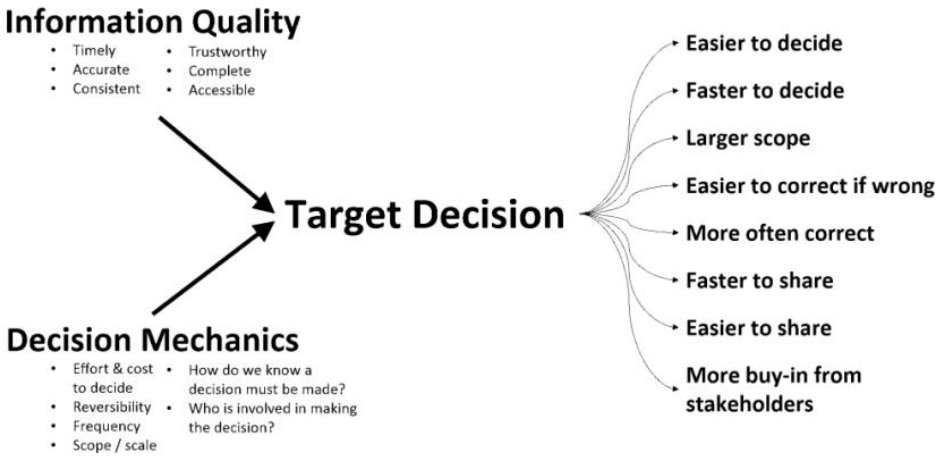


Figure 35: How a visibility solution could improve a target decision

These metrics are diagnostic tools for assessing the health of the visibility sub-processes.

The key enablers/process steps of SCV	The score-card metrics which was used by the approach
Capture Data →	Sensitivity A highly sensitive solution captures all the needed data
Integrate Data →	Accessibility The ease of moving between data objects, either as person or for automated processes
Create Intelligence →	Intelligence How effective is the solution at separating the necessary from unnecessary data
Interrupt Decisions →	Relevance How much is the target decision being interrupted or changed by the visibility solution

Figure 36: Supply chain visibility scorecard metrics association with key enablers

Annex 6.7 Supply chain performance indicators analysis

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Stock-out rates

This indicator measured the percentage of facilities (in this case are the eleven PFSA hubs) that experienced a stock out of the three selected products that the site is expected to provide, at any point, within 2015 (for one year). The hubs are the main part of the focal company, which are responsible to warehouse products and conduct delivery to health facilities.

$$\frac{\text{number of facilities that experienced a stockout of a specific product}}{\text{total number of facilities that are expected to offer that product}} * 100$$

Table 19; Stock-out rates

Product Group	*Product name*	*Number of hubs that experienced a stock-out of a specific product during a defined period of time (within 2015)*	*Total number of hubs that are expected to offer that product.*	*Percentage of stock-out rates*
RDF/INT	CAF inj[4]	4	11 Hubs	36.3%
RDF/LOC	Amox 500[5]	0	11 Hubs	0%
PROG/INT	3TC/TDF/EFV-adult[6]	3	11 Hubs	27.2%

Plan in place for predictable change in demand

This indicator assessed whether the focal company has a plan or procedures in place to adjust stock levels to respond to seasonal variance in demand and/or certain campaigns that require surges in stock levels.

Is there a formal plan or are there procedures in place to respond to seasonal variance in demand and/or certain campaigns that require adjustments in stock levels? (Yes/no)

From the focal company's perspective, a ***'Monthly stock status monitoring'*** is done. This report tracks quantity at all hubs, at central warehouses and on pipeline. Hub forecasting and capacity building officers send reports constituting hubs list of products stock status to the main office through email. The report is compiled after a reconciliation of values from the HCMIS (Health commodities management information system) database and a manually filled paper bin-card.

[4] Chloramphenicol Sodium Succinate 1gm injection of 50 vials
[5] Amoxicillin 500mg capsule
[6] Lamivudine 300mg/Tenofovir 300mg/Efavirenz 600mg of 30

Plan in place	Hubs (Warehouses)										
	AA	Jimma	Hawassa	Bahirdar	Mekelle	Gonder	Dessie	Diredawa	Nekemte	Adama	Arbaminch
Does the hub conduct monthly stock status monitoring	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

Order lead time

This indicator measured the average amount of time it takes from when an order is placed from the focal company to a higher-level supplier to when the ordering facility (the focal company-PFSA) receives its shipment during a specified period of time. This indicator is usually recorded in days but can be calculated over any period of time.

$$\frac{\text{sum of the number of days between when orders were placed and when orders were received}}{\text{total number of orders placed}}$$

Table 20; Order Lead time

Product Group	**Product name**	**Dates when orders were placed** ***(is Date when purchase order is given to the supplier)***	**Dates when orders were received (*Date when first shipment is received)***	**Average Order Lead-Time**
RDF/INT	CAF inj	3 separate orders placed on the day 19/10/2015	None reached yet, • Order 1 : shipped on March 9,2016 may arrive after May 9,2016 (is by sea) • Order 2: will be shipped soon (Not shipped yet) • Order 3: will be shipped after order 2	None reached yet,
RDF/LOC	Amox 500	27/7/15	1/9/2015	1 month
PROG/INT	3TC/TDF/EFV-adult7	30/10/2014[8]	22/01/2015	1 month

Percentage of orders placed through electronic ordering system

Electronic ordering system here refers to an IT-system used, while conducting a purchase or an order, for direct communication with the supplier's IT-system with no humans involved.

This indicator measured, orders placed through an electronic ordering system in the first 6 months of 2015.

$$\frac{\text{number of orders placed through electronic system}}{\text{total number of orders placed}} * 100$$

[7] Lamivudine 300mg/Tenofovir 300mg/Efavirenz 600mg of 30
[8] Data grabbed only for one of the orders

Table 21; Percentage of orders placed through electronic ordering system

Product Group	*Product name*	*Total number of orders placed in the first 6 months of 2015*	*Number of orders placed through an electronic system*	*Percentage of orders placed through an electronic system*
RDF/INT	CAF inj	1	None	0%
RDF/LOC	Amox 500	1	Letter from forecasting to procurement directorate	Orders made through
PROG	3TC/TDF/EFV-adult	2	None Orders from hospitals to PFSA are by using report and requisition formats i.e. ***both ordering are manual***	-Letter -RRF[9]

Supplier Fill rate

A supplier's ability to fill orders completely in terms of quantity during a definite period of time is calculated. Those cases where agreements are made between supplier and recipient to divide an order into multiple shipments but still be received, in full, by a specified date, or that substitutes can be made were also considered.

$$\frac{\text{number of order lines/SKUs/cases shipped in initial shipment}}{\text{total quantity ordered}} * 100$$

[9] RRF-Report and Requisition Format

Table 22; Supplier fill rate

Product Group	*Product name*	*Total quantity ordered in original PO*	*Number of order SKU shipped in initial shipment*	*Supplier fill rate*
RDF/INT	CAF inj	50,000	50,000	100%
RDF/LOC	Amox 500	378,802	9,012 (Is directly shipped from local manufacturers to PFSA hubs within the first three months)	100% [10]The Local suppliers has an agreement with the focal company to deliver the total amount ordered being broken down in units and each quarters of the year. 9,012 is what is delivered for one quarter. But they have met the total order amount at the end of the year.
PROG/INT	3TC/TDF/EFV-adult	994,159	994,159	100%

Forecast accuracy error

For all products that the program has committed to supplying, this indicator measures the difference between forecasts previously made for a year and the actual consumption or issues data for that year. The calculation is based on the mean absolute percentage error (MAPE), usually expressing accuracy as a percentage, and is defined by the formula:

$$\mathrm{M} = \frac{1}{n}\sum_{t=1}^{n}\left|\frac{A_t - F_t}{A_t}\right|,$$

[10] Special Condition

where A_t is the actual value and F_t is the forecast value and n is the number of forecasting point in time.

The difference between At and Ft is divided by the Actual value At . The absolute value of the result gives the mean absolute error.

The indicator is calculated for each product for which a forecast is made.

The data used for forecast is adjusted for this calculation because of the following reason. One, focal company's actual consumption means that of the quantity where hubs have issued to health facilities during a year. Hubs report this quantity of issue data every six months. Therefore, the data available for actual consumption of a product is of 6 months. Therefore, in order to align the forecast which normally is made for a year, it is divided into two and adjusted to give forecast of a half year (for the purpose of calculating forecast error).

Table 23; Forecast accuracy error for the year 2015

Product Group	*Product name*	*Adjusted Forecast for half-year*[11]	*Actual consumption or issues data (is for 6months of 2015)*	*Forecast* [12]*Accuracy*
RDF/INT	CAF inj	42,733	11,879	2.59
RDF/LOC	Amox 500	208,971	166,999	0.25
PROG	3TC/TDF/EFV-adult	1,355,392	1,104,546	0.22

Percentage of Purchase Orders/Contracts Issued As Emergency Orders

The percentage of purchase orders that are issued as emergency, with a lead time of one month or less, out of all purchase orders or contracts placed during 2015 is measured.

$$\frac{\text{number of emergency orders}}{\text{total number of orders placed}} * 100$$

11 (Full Year Forecast for 2015 –CAF Inj- 85,466 , Amox 500 -417,943, FDC-2,710,785)

[12] 0 is the ideal value, and as the forecast becomes poor, the value appear far away from 0.

Table 24; Percentage of emergency orders

Product Group	*Product name*	*Total number of orders placed (within 2015)*	*Number of emergency order requests (within 2015)-those orders with a lead time of one month or less*	*Percentage of emergency orders*
RDF/INT	CAF inj	3 POs	0	0
RDF/LOC	Amox 500	2 POs	0	0
PROG	3TC/TDF/EFV-adult	5 POs	1	20%

Annex 6.8

Table 25; Availability of vital pharmaceuticals on season of data collection by hub type, April 2016

Products	*Hubs*	*Stock A*	*Total*
Nifedipine 20mg tablet	6	6	100.0
Insulin zinc suspension 100IU/ml injection	6	4	66.7
Chloramphenicol Sodium Succinate 1gm injection	6	5	83.3
Erythromycin (as Stearate) tablet - 250 mg, 500mg	6	6	100.0
Gauze Surgical 90cmx100 m mesh size 19x15	6	6	100.0
Surgical gloves sterile latex No. 7.5	6	1	16.7
T.A.T. 1500IU/ml injection	6	4	66.7
Cimetidine 200mg/ml, 2ml injection	6	5	83.3
Cotrimoxazol Suspension 240mg/5ml	6	5	83.3
Amoxicillin 250mg,500mg tablet	6	6	100.0
Ciprofloxacin 500mg Tablet	6	4	66.7
Lamivudine 300mg/Tenofovir 300mg/Efavirenz 600mg Tablet	6	6	100.0
Zidovudine 300mg/Lamivudine 150mg/Nevirapine 200mg Tablet	6	6	100.0
RHZE (150mg+75mg+400mg+275mg) , RH- (150mg+75mg)	6	6	100.0
Artemether + lumefanthrine (20 +120)mg	6	6	100.0
Medroxyprogesterone acetate 150mg/ml injection	6	5	83.3
			84.4

Annex 6.9

Table 26; Availability of vital pharmaceuticals in six months prior to survey by hub type, April 2016

Products	Hubs	Stock A	Total
Nifedipine 20mg tablet	6	5	83.33
Insulin zinc suspension 100IU/ml injection	6	3	50.00
Chloramphenicol Sodium Succinate 1gm injection	6	5	83.33
Erythromycin (as Stearate) tablet - 250 mg, 500mg	6	4	66.67
Gauze Surgical 90cmx100 m mesh size 19x15	6	1	16.67
Surgical gloves sterile latex No. 7.5	6	2	33.33
T.A.T. 1500IU/ml injection	6	1	16.67
Cimetidine 200mg/ml, 2ml injection	6	1	16.67
Cotrimoxazol Suspension 240mg/5ml	6	5	83.33
Amoxicillin 250mg,500mg tablet	6	6	100.00
Ciprofloxacin 500mg Tablet	6	4	66.67
Lamivudine 300mg/Tenofovir 300mg/Efavirenz 600mg Tablet	6	6	100.00
Zidovudine 300mg/Lamivudine 150mg/Nevirapine 200mg Tablet	6	6	100.00
RHZE (150mg+75mg+400mg+275mg) , RH- (150mg+75mg)	6	4	66.67
Artemether + lumefanthrine (20 +120)mg	6	6	100.00
Medroxyprogesterone acetate 150mg/ml injection	6	5	83.33
			66.67%

Annex 7.0

Table 27: The quantity, accuracy and freshness of the exchanged information, focal company with local manufacturers

Semi-quantitative judgments	Transaction/Events	Status Information	Master Data	Operational Data
The quantity of information local suppliers generates	11	3	7	3
How many of those generated information does the focal company access	10	3	7	3
How many in percentage does the focal company access	91.6%	100%	100%	100%
The scale to judge the quantity of the exchanged information	4 The focal company has access to a large part of the	4 The focal company has access to a large part of the	4 The focal company has access to a large part of the	4 The focal company has access to a large part of the

based on table 14 metrics	information within this category	information within this category	information within this category	information within this category
How the focal company rated accuracy of the information they already access	Scale of 4 , 6 of them Scale of 3 , 2 of them Scale of 2 , 2 of them	Scale of 2, 1 of them Scale of 3, 2 of them	Scale of 3, 4 of them Scale of 4, 3 of them	Scale of 4, 1 of them
The scale to judge accuracy of the exchanged information based on table 15 metrics	3 The accuracy of the exchanged information is usually satisfactory but the information is incorrect only in a few situations	3 The accuracy of the exchanged information is usually satisfactory but the information is incorrect only in a few situations	3 The accuracy of the exchanged information is usually satisfactory but the information is incorrect only in a few situations	4 The accuracy of the exchanged information is very good
How the focal company rated freshness of the information they already access	Scale of 1, 11 of them	Scale of 2, 3 of them	Scale of 1, 7 of them	Scale of 2, 1 of them
The scale to judge Freshness of the exchanged information based on table 16 metrics (How frequently the information is updated?)	1 Less than once a day	2 Information is updated only when the node is asked to provide data	1 Monthly or less than once a month	2 Information is updated only when the node is asked to provide data

Table 28: The quantity, accuracy and freshness of the exchanged information, Focal Company with International Manufacturers

Semi-quantitative judgments	*Transaction/Events*	*Status Information*	*Master Data*	*Operational Data*
The quantity of information international suppliers generate	13	2	6	3
How many of those generated information does the focal company access	12	2	6	3
How many in percentage does the focal company access	92.3%	100%	100%	100%

The scale to judge the quantity of the exchanged information based on table 14 metrics	4 The focal company has access to a large part of the information within this category	4 The focal company has access to a large part of the information within this category	4 The focal company has access to a large part of the information within this category	4 The focal company has access to a large part of the information within this category
How the focal company rated accuracy of the information they already access	Scale of 3, 7 of them Scale of 2, 4 of them Scale of 4, 1 of them	Scale of 2, 2 of them	Scale of 3, 3 of them Scale of 4, 3 of them	Scale of 3, 3 of them
The scale to judge accuracy of the exchanged information based on table 15 metrics	3 The accuracy of the exchanged information is usually satisfactory but the information is incorrect only in a few situations	2 The accuracy of the exchanged information is usually satisfactory but situations in which the information is incorrect are not uncommon	3 The accuracy of the exchanged information is usually satisfactory but the information is incorrect only in a few situations	3 The accuracy of the exchanged information is usually satisfactory, but the information is incorrect only in a few situations
How the focal company rated freshness of the information they already access	Scale of 1, 12 of them	Scale of 2, 2 of them	Scale of 2, 6 of them	Scale of 2, 2 of them
The scale to judge Freshness of the exchanged information based on table 16 metrics (How frequently the information is updated?)	1 Less than once a day	1 Information is updated only when the node is asked to provide data	2 Weekly update of those information	2 Information is updated only when the node is asked to provide data

Annex 7.1
Localization,

In this case, as all the suppliers in the inbound supply chain are on the first tier list, the localization measure is **1**(one).

Significance in terms of value of the goods supplied

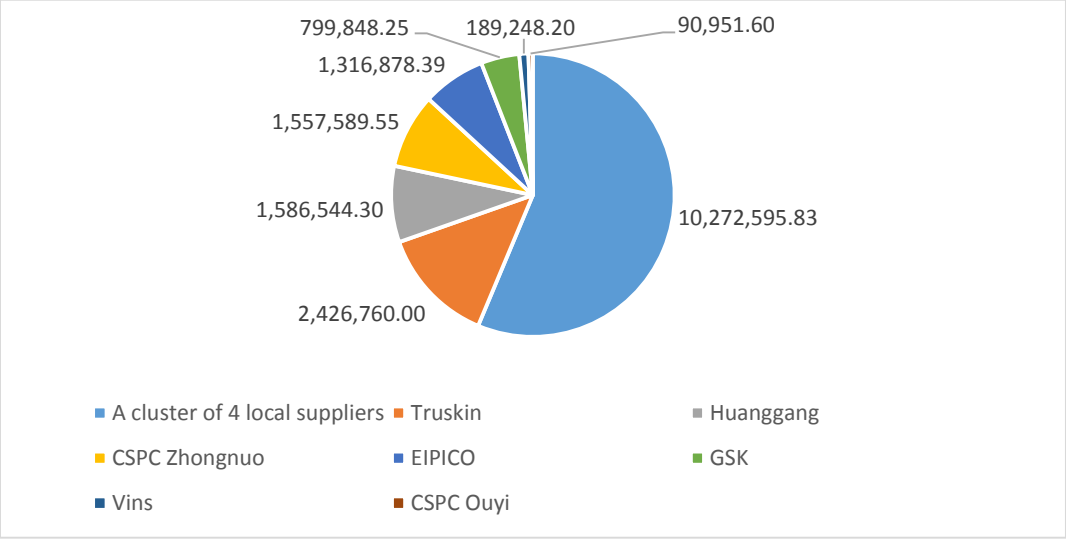
After reviewing the annual purchase report for 2015 of those 11(eleven) items, the cumulative total amount of purchase made from the suppliers is listed. The list of suppliers over the year with respect to the total amount in sales they have supplied to the focal company is then ranked as follows.

Annex 7.2

Criticality estimation

Table 29: RDF Suppliers versus focal company Significance Table

Ranking	*List of Supplier for RDF pharmaceuticals based on the purchasing power*	*Total amount in USD the focal company purchased*	*Origin of the Supplier*	*Items they normally Supplied during the year*
1	A cluster of local suppliers APF Epharm Cadilla East Africa	10,272,595.826	Ethiopia	Erythromycin 250mg,Amoxicillin 250mg/500mg,Ciprofloxacilin 500mg Tablet
2	Truskin Glove Pvt.Ltd	2,426,760.00	India	Surgical gloves sterile latex No. 7.5
3	Huanggang Hyangzhou	1,586,544.30	China	Gauze Surgical 90cmx100 m mesh size 19x15
4	CSPC Zhongnuo Pharmaceutical	1,557,589.55	China	Chloramphenicol Sodium Succinate 1gm injection
5	Egyptian International EIPICO	1,316,878.39	Egypt	Insulin zinc suspension 100IU/ml injection
6	GlaxoSmithKline (GSK)	799,848.25	UK	Nifedipine 40mg, Erythromycin (as Stearate) 500mg tablet
7	Vins Biopoducts LTD	189,248.20	India	T.A.T. 1500IU/ml injection
8	CSPC Ouyi Phar	90,951.60	China	Cimetidine 200mg/ml, 2ml injection



[13] Nifedipine 40mg substitute
[14] 894,618USD-Erytro 250mg(2014 purchase), 6,614,077USD-Amox250/500mg, 2,776,930.43USD – Cipro5oomgtab
[15] Truskin (Data of 2014)
[16] 1 USD =23 ETB

List of Supplier for RDF pharmaceuticals based on the purchasing power	Total amount in USD the focal company purchased	wsigk, significance weight of each node	Based on criticality four (4) response scale	
			Criticality of the item the supplier supplies from a strategic perspective (The item is critical which can't be substituted with another item)	Existence of other suppliers for the item the supplier supplies
A cluster of local suppliers	10,272,595.826	0.56317771	2	International Suppliers
APF				
Epharm				
Cadilla				
East Africa				
Truskin Glove Pvt.Ltd	2,426,760.00	0.13304302	2	International Suppliers
Huanggang Hyangzhou	1,586,544.30	0.08697961	2	Suzhou Industrial Win
CSPC Zhongnuo Pharmaceutical	1,557,589.55	0.08539222	2	Macleodes Pharmaceutical Limited,
Egyptian International EIPICO	1,316,878.39	0.07219563	2	International Suppliers
GlaxoSmithKline (GSK)	799,848.25	0.04385033	2	EIPICO
Vins Biopoducts LTD	189,248.20	0.01037521	2	Vacsera
CSPC Ouyi Phar	90,951.60	0.00498627	2	International Suppliers
Sn, FC – Total purchase amount of Focal Company	**18,240,416.12**			

Table 30: Overall visibility by Information quantity and quality

Table 31: Significance weight and criticality measurement estimation

$= \sum_{k=1}^{N} (\text{Node\_visibility\_quantity}_k \cdot = \sum_{k=1}^{N} (\text{Node\_visibility\_accuracy}_k \cdot = \sum_{k=1}^{N} (\text{Node\_visibility\_freshness}_k \cdot \quad = \sum_{k=1}^{N} (\text{Node\_visibility\_quality}_k \cdot$

Nodes	Wstd,k	Node_Vis Quantity	Total amount of visible information	Node_Vis Accuracy	Accuracy of the overall visible information	Node_Vis Freshness	Freshness of the overall visible information	Node_Vis Quality	Quality of the overall visible information
A cluster of local suppliers	0.31894	4	1.27576	3.22	1.0269	1.41	0.4497	2.13	0.6793
Truskin Glove Pvt.Ltd	0.15502	4	0.62008	2.71	0.4201	1.41	0.2185	1.95	0.3022
Huanggang Hyangzhou	0.12534	4	0.50136	2.71	0.3396	1.41	0.1767	1.95	0.2444
CSPC Zhongnuo Pharmaceutical	0.12419	4	0.49676	2.71	0.3365	1.41	0.1751	1.95	0.2421
Egyptian International EIPICO	0.11419	4	0.45676	2.71	0.3094	1.41	0.1610	1.95	0.2226
GlaxoSmithKline (GSK)	0.08899	4	0.35596	2.71	0.2411	1.41	0.1254	1.95	0.1735
Vins Biopoducts LTD	0.04329	4	0.17316	2.71	0.1173	1.41	0.0610	1.95	0.0844
CSPC Ouyi Phar	0.03001	4	0.12004	2.71	0.0813	1.41	0.0423	1.95	0.058
			4		2.87		1.4099		2.0

Overall visibility of type i of information(OV)

$$\sum_{k=1}^{N} (\text{Node\_partial\_visibility}_{k,i} \cdot W_{\text{std},k})$$

Total amount of visible information of type i(TA)

$$\sum_{k=1}^{N} (j_{q,i,k} \cdot W_{\text{std},k})$$

Nodes	Node_partial_visibility								Jq,j,k(Quantity)			
	Wstd,k	T/E		SI		MD		OD		T/E	SI	MD	OD
A cluster of local suppliers	0.31894	2.28	0.72	2.88	0.91	2.28	0.72	3.17	0.80	4	4	4	4
Truskin Glove Pvt.Ltd	0.15502	2.28	0.35	2	0.31	2.88	0.44	2.88	0.44	4	4	4	4
Huanggang Hyangzhou	0.12534	2.28	0.28	2	0.25	2.88	0.36	2.88	0.36	4	4	4	4

CSPC Zhongnuo Pharmaceutical	0.12419	2.28	0.28	2	0.24	2.88	0.35	2.88	0.35	4	4	4	4
Egyptian International EIPICO	0.11419	2.28	0.26	2	0.22	2.88	0.32	2.88	0.32	4	4	4	4
GlaxoSmithKline (GSK)	0.08899	2.28	0.20	2	0.17	2.88	0.25	2.88	0.25	4	4	4	4
Vins Biopoducts LTD	0.04329	2.28	0.09	2	0.08	2.88	0.12	2.88	0.12	4	4	4	4
CSPC Ouyi Phar	0.03001	2.28	0.06	2	0.06	2.88	0.08	2.88	0.08	4	4	4	4
			2.28		2.28		2.68		2.97	4			

Accuracy of the overall visible information of type i

$$\sum_{k=1}^{N}(j_{a,i,k}\cdot W_{\mathrm{std},k})$$

Freshness of the overall visible information of type i

$$\sum_{k=1}^{N}(j_{f,i,k}\cdot W_{\mathrm{std},k})$$

	Ja,j,k (Accuracy)									Jf,j,k (Freshness)							
Nodes	Wstd,k	T/E		SI		MD		OD		T/E		SI		MD		OD	
A cluster of local suppliers	0.31894	3	0.957	3	0.957	3	0.95	4	1.276	1	0.31	2	0.638	1	0.31	2	0.63
Truskin Glove Pvt.Ltd	0.15502	3	0.465	2	0.310	3	0.46	3	0.465	1	0.15	1	0.155	2	0.31	2	0.31
Huanggang Hyangzhou	0.12534	3	0.376	2	0.251	3	0.37	3	0.376	1	0.12	1	0.125	2	0.25	2	0.25
CSPC Zhongnuo Pharmaceutical	0.12419	3	0.373	2	0.248	3	0.37	3	0.373	1	0.12	1	0.124	2	0.24	2	0.24
Egyptian International EIPICO	0.11419	3	0.343	2	0.228	3	0.34	3	0.343	1	0.11	1	0.114	2	0.22	2	0.22
GlaxoSmith Kline (GSK)	0.08899	3	0.267	2	0.178	3	0.26	3	0.267	1	0.08	1	0.089	2	0.17	2	0.17
Vins Biopoducts LTD	0.04329	3	0.130	2	0.087	3	0.13	3	0.130	1	0.04	1	0.043	2	0.08	2	0.08
CSPC Ouyi Phar	0.03001	3	0.090	2	0.060	3	0.09	3	0.090	1	0.03	1	0.030	2	0.06	2	0.06
			3		2.319		3		3.319		1		1.319		1.68		2.00

Table 32: Overall visibility by type of information

Annex 7.3

Table 33: The quantity, accuracy and freshness of exchanged information, program suppliers

Semi-quantitative judgments	*Transaction/Events*	*Status Information*	*Master Data*	*Operational Data*
The quantity of information the international program drug supplier generates	13	2	6	3
How many of those generated information does the focal company access	12	2	6	3
How many in percentage does the focal company access	92.3%	100%	100%	100%
The scale to judge the quantity of the exchanged information based on table 7 metrics	4 The focal company has access to a large part of the information within this category	4 The focal company has access to a large part of the information within this category	4 The focal company has access to a large part of the information within this category	4 The focal company has access to a large part of the information within this category
How the focal company rated accuracy of the information they already access	Scale of 4 , 3 of them Scale of 3 , 9 of them	Scale of 2, 1 of them Scale of 3, 1 of them	Scale of 4, 5 of them Scale of 3, 1 of them	Scale of 3, 1 of them Scale of 4, 2 of them
The scale to judge accuracy of the exchanged information based on table 8 metrics	3 The accuracy of the exchanged information is usually satisfactory, and the information is incorrect only in a few situations	3 The accuracy of the exchanged information is usually satisfactory, and the information is incorrect only in a few situations	3 The accuracy of the exchanged information is usually satisfactory but the information is incorrect only in a few situations	3 The accuracy of the exchanged information is usually satisfactory but the information is incorrect only in a few situations
How the focal company rated freshness of the information they already access	Scale of 1, 12 of them	Scale of 2, 2 of them	Scale of 2, 6 of them	Scale of 2, 3 of them
The scale to judge Freshness of the exchanged information based on table 9 metrics (How frequently the information is updated?)	1 Less than once a day	2 Information is updated only when the node is asked to provide data	2 Information is updated on a weekly basis	2 Information is updated only when the node is asked to provide data

Annex 7.4
Table 27.0 [17]

Table 34: Significance weight and criticality measurement at each node

Suppliers (n =12)	*Sk, FC- Focal company Purchase amount, 2015 USD*	*wsigk, significance weight of each node*	*Based on criticality four response scale, table 11*	
			Criticality of the item the supplier supplies from a strategic perspective (The item is critical which can't be substituted with another item)	Existence of other suppliers for this item the supplier supplies
Auro bindo Pharma Limited	44,440,796.93	0.848132768	2	Cipla, Macleods Pharmaceuticals, Mylan Lab Ltd, Hetero
Strides Arcolab Limited	2,890,337.00	0.055160791	4	
Macleods Pharmaceutical Limited	2,790,644.00	0.053258195	4	
San Pharmaceutical Industries Ltd	2,276,618.40	0.043448246	2	CIPLA, Cipla Ltd, Mumbai
Sn, FC – Total purchase amount of Focal Company	52,398,396.33			

[17] Aurobindo ; 29,036,215.23 USD – 3TC/TDF/EFZ , 15,404,581.70 USD –ZDV/3TC/NVP

	$=\sum_{k=1}^{N}(\text{Node\_visibility\_quanti}$		$=\sum_{k=1}^{N}(\text{Node\_visibility\_accura}$		$=\sum_{k=1}^{N}(\text{Node\_visibility\_freshne}$		$=\sum_{k=1}^{N}(\text{Node\_visibility\_quali}$		
Nodes		Wstd,k	Node_Vis Quantity	Total amount of visible information	Node_Vis Accuracy	Accuracy of the overall visible information	Node_Vis Freshness	Freshness of the overall visible information	Node_Vis Quality	Quality of the overall visible information
Cluster of ***Program*** *International suppliers*	52,398,396.3	0.74	4	2.96	3	2.22	1.68	1.2432	2.24	1.6576
Cluster of ***local*** *suppliers*	10,272,595.826	0.15	4	0.6	3.22	0.483	1.41	0.2115	2.13	0.3195
Cluster of ***RDF international*** *suppliers*	7,967,820.294	0.112	4	0.448	2.71	0.3035	1.41	0.15792	1.95	0.2184
	70,638,812.45		4			3.0065		1.61262		2.1955

Table 35: Global visibility measure by quantity, quality and type of information for all the suppliers (Local, RDF International and Program International

Overall visibility of type i of information(OV)

$$\sum_{k=1}^{N} (\text{Node\_partial\_visibility}_{k,i} \cdot W_{\text{std},k})$$

Total amount of visible information of type i(TA)

$$\sum_{k=1}^{N} (j_{q,i,k} \cdot W_{\text{std},k})$$

Nodes	Node_partial_visibility								Jq,j,k(Quantity)			
	Wstd,k	T/E	SI	MD	OD				T/E	SI	MD	OD
Cluster of ***Program*** *International suppliers*	0.74	2.2	1.6	2.88	2.1	2.88	2.1	2.88				
Cluster of ***local suppliers***	0.15	2.2	0.3	2.88	0.43	2.28	0.34	2.51	0.37			
Cluster of ***RDF international*** *suppliers*	0.112	2.28	0.25	2	0.22	2.88	0.32	2.88	0.32			
			2.28		2.78		2.79		2.83		4	

Accuracy of the overall visible information of type i

$$\sum_{k=1}^{N} (j_{a,i,k} \cdot W_{\text{std},k})$$

Freshness of the overall visible information of type I

$$\sum_{k=1}^{N} (j_{f,i,k} \cdot W_{\text{std},k})$$

Nodes	Ja,j,k (Accuracy)						Jf,j,k (Freshness)					
	Wstd,k	T/E	SI	MD	OD		T/E	SI	MD	OD		
Cluster of ***Program*** *International suppliers*	0.74	3	3	2.22	3	3	2.22	1	2	1.48	2	1.48	2
Cluster of ***local*** *suppliers*	0.15	3	3	0.45	3	4	0.6	1	2	0.3	1	0.15	2
Cluster of RDF ***international*** *suppliers*	0.112	3	2	0.224	3	3	0.33	1	1	0.112	2	0.22	2
												.85	2

Table 36: Overall visibility by Information quantity and quality

Annex 7.5

Table 37 : APTS, Hospital activity flow for RDF products

APTS Activity Flow			Information Flow exchanged	Responsible Person	Forms Used
Client/patient arrives with a prescription					
Professional Checks the validity and legitimacy of the prescription			Patient personal Information; Name, Age and Address Patient Diagnosis Patient Disease Prescription Information Drug name, ROA, Strength Physician Information	Evaluator(Pharmacist by Profession)	Patient Catalog Book
	If the Drug is stock-out or Unavailable		Stock out	Evaluator Coordinator Store Man DSM (Drug Supply M.)	Personal Note **IFRR** **HMIC** **RRF**
		Patient/Client will be told to buy from; Special Pharmacy or Outside Pharmacy	Product issued from Special Pharmacy	Dispenser	
	Stocked out //unavailable items are reported to unit coordinator		Stocked out list	Evaluator	Personal Note
	Stocked out Product request Order is sent to store-man		Stocked out product list request	Coordinator	**IFRR** (Internal Facility Requisition and Reporting format)
	If product is in store, store-man refills the pharmacy		Pharmacy outlet stock refill Warehouse stock issued	Store-man Coordinator	**Bin-card** **Stock-card** **Model-20**

			If product is also stocked out in store, purchase order list is generated and sent to PFSA	Purchase order generated Purchase order sent	DSM(Drug Supply Manager) CCO(Chief Clinical Officer) CEO (Chief Executive Officer)	**RRF (Report and Requisition format)** **Formal Letter** **Product Purchase format**
			If product is available in PFSA, hospital will be filled with stock.	Store Product receive Product Stock status updated	DSM Store-man	**Invoice** **Model-19** **Bin-card** **Stock-card**
			Payment for PFSA generated and completed	Payment initiated Payment Completed	Finance Accountant	**Invoice** **Model-19** **Payment Voucher**
		If product is not available in PFSA, Purchase order is redirected to Private Suppliers		PFSA Stock out	PFSA Distribution Officer	**Stock-out list paper**
If the drug is in Stock,						
	Client/Patient Pays **Cash** or get registered for **Credit** payment			Cash paying Client Credit Client	Casher	Cash Receipt Credit Registry
If Client is a 'free' user, no need of passing through the casher				Free Patient status	Evaluator	Free Patients Registry Book
Client /Patient Receives the Medicine				Medicine Issued Drug Stock Status Updated	Dispenser	
	Patient/Client will get a detailed counselling or Orientation				Counselor	

Prescription Archived And Patient/Client Exits		Transaction Completed	Data Clerk	Internal prescription archiving folders
At the end of the day, Document cross-checking is conducted		Correctly crosschecked Document mismatched	Accountant Auditor	Patient Catalog Book Prescription Archive

Annex 7.6

Table 38 : Measuring the quantity and quality of information accessed by the focal company (RDF/Hospitals)

Semi-quantitative judgments	*Transaction/Events*	*Status Information*	*Master Data*	*Operational Data*
The quantity of information the hospital generates	12	6	7	2
How many of those generated information does the focal company access	10	6	2	2
How many in percentage does the focal company access	83.3 %	100 %	28.5 %	100%
The scale to judge the quantity of the exchanged information based on table 8 metrics	3 The focal company has access to a large part (more than 75 per cent) of the information within this category	4 The focal company has access to a large part (more than 75 per cent) of the information within this category	2 The focal company has partial access (between 25 and 50 per cent) to the information with this category	4 The focal company has access to a large part (more than 75 per cent) of the information within this category
How the focal company rated accuracy of the information they already access	Scale of 3 , 10 of them	Scale of 2, 6 of them	Scale of 3, 1 of them Scale of 2, 1 of them	Scale of 2, 2 of them
The scale to judge accuracy of the exchanged information based on table 9 metrics	3 The accuracy of the exchanged information is usually satisfactory but the information is incorrect only in a few situations	2 The accuracy of the exchanged information is usually satisfactory, but situations in which the information is incorrect are not uncommon	2 The accuracy of the exchanged information is usually satisfactory, but situations in which the information is incorrect are not uncommon	2 The accuracy of the exchanged information is usually satisfactory, but situations in which the information is incorrect are not uncommon
How the focal company rated freshness of the information they already access	Scale of 1, 10 of them	Scale of 1, 6 of them	Scale of 1, 1 of them Scale of 3, 1 of them	Scale of 2, 1 of them
The scale to judge Freshness of the exchanged information based on table 10 metrics (How frequently the information is updated?)	1 Less than once a day	1 unsatisfactory	1 Monthly or less than once a month. The information is gathered only when the focal company is makes a request and contacts the focal company.	2 Information is updated only when the node is asked to provide data.

Annex 7.7

Table 39: IPLS, Hospital activity flow for Program products

IPLS Activity Flow				Information Flow exchanged	Responsible Person	Forms Used
	ART (-3TC 300mg/TDF 300mg/EFZ 600mg Tab,30 -AZT 300mg/3TC 150mg/NVP 200mg Tab, 60)					
	Patient/ Client comes in every 60 days	New patient may be referred at anytime	Patient /Client on an emergency case can also appear at any time	-Patient Registry is updated -Drug Information - Treatment Progress Information	Pharmacist/ Dispenser	EDT (Electronic Dispensing Tool)
		If stock is in store				
		Patient/Client is refilled or Issued Regimen		Medicine first time issued Medicine Refilled	Pharmacist/ Dispenser	
	If stock is unavailable, Emergency request is initiated			ART product Stock out Program product Stock out Emergency product request	Pharmacist/ Dispenser	Product request format Formal Letter
	Emergency product			Emergency Stock	Store-Man	STV(Stock Transf

			request fulfilled		Updated	Dispenser	er Voucher) Model-19
			Regular Product request is initiated every 2 months		Weekly inter facility request Monthly outer facility product requisition	Pharmacist/ Dispenser Store Man DSM CEO	IFRR (Internal Facility Reporting Format) RRF
			4 months of stock based on the RRF sent is received from PFSA		Monthly Stock refilled	Store-Man PFSA Deliverer	EDT HCMIS STV Model-19 Stock card Bin card
	TB RHZE of 12x28, Kit (DOT)						
		Continuing Patient comes every day-for refill for 2 mnth			-Patient Registry is updated -Drug Information - Treatment Progress Information	Pharmacist/ Dispenser	Patient and Drug registry catalog
		New Patient starts treatment					
The rest processes go the same as ART							
	Malaria Artemether + lumefanthrine(20				-Patient Registry is updated	Pharmacist/ Dispenser	Patient and Drug registry

		+120) Mg 6X4, 30			-Drug Information -Treatment Progress Information		catalog
		New patient diagnosed with falciparum comes in					
The rest processes go the same as ART							
Family Planning Medroxyprogesterone acetate 150mg/ml in 1ml, Vial							
A client comes in every three months	A new client comes in				-Patient Registry is updated -Drug Information -Treatment Progress Information	Pharmacist/ Dispenser	Patient and Drug registry catalog
The rest processes go the same as ART							

Annex 7.8

Table 40: Measuring the quantity and quality of information accessed by the focal company (Program/Hospitals)

Semi-quantitative judgments	*Transaction/Events*	*Status Information*	*Master Data*	*Operational Data*
The quantity of information the hospital generates	7	7	6	4
How many of those generated information does the focal company access	7	7	5	4
How many in percentage does the focal company access	100%	100%	83.3%	100%
The scale to judge the quantity of the exchanged information based on table 8 metrics	4 The focal company has access to a large part (more than 75 per cent) of the information within this category	4 The focal company has access to a large part (more than 75 per cent) of the information within this category	4 The focal company has access to a large part (more than 75 per cent) of the information within this category	4 The focal company has access to a large part (more than 75 per cent) of the information within this category
How the focal company rated accuracy of the information they already access	Scale of 2 , 2 of them Scale of 3 , 3 of them Scale of 4 , 2 of them	Scale of 3, 5 of them Scale of 4, 2 of them	Scale of 2, 2 of them Scale of 3, 2 of them	Scale of 3, 2 of them Scale of 1, 4 of them
The scale to judge accuracy of the exchanged information based on table 9 metrics	3 The accuracy of the exchanged information is usually satisfactory but the information is incorrect only in a few situations	3 The accuracy of the exchanged information is usually satisfactory but the information is incorrect only in a few situations	2 The accuracy of the exchanged information is usually satisfactory, but situations in which the information is incorrect are not uncommon	2 The accuracy of the exchanged information is usually satisfactory, but situations in which the information is incorrect are not uncommon
How the focal company rated freshness of the information they already access	Scale of 1, 4 of them Scale of 4, 2 of them Scale of 2, 1 of them	Scale of 2, 4 of them Scale of 4, 2 of them Scale of 3, 1 of them	Scale of 3, 2 of them Scale of 1, 4 of them	Scale of 2, 2 of them Scale of 4, 2 of them
The scale to judge Freshness of the exchanged information based on table 10 metrics (How frequently the information is updated?)	1 Less than once a day	3 In some cases information is updated only when the node is asked to provide data	1 Monthly or less than once a month. The information is gathered only when the focal company is makes a request and contacts the focal company.	2 Information is updated only when the node is asked to provide data.

Annex 7.9

Product availability table survey for PFSA hubs

TABLE DESCRIPTION

Products specified from 1-11 are under the RDF while those from 12-16 are under PROGRAM

Column:

1. Name of all authorized products
2. Unit of count for the product Note
3. Unit cost for the product Note

Columns 1, 2 and 3 will be filled out before questionnaires are printed for the survey.

4. Is product available in stock, answer Y for yes or N for no.
5. What is the expiry date of the respective product in stock?
6. If product is available in stock, what is the current updated balance reading from the bin-card or HCMIS?
7. Have you experienced any stock outs within most recent of 6 months (from 1/10/2015 – 1/03/2016)
8. If any stock-outs within the full year, can you remember the number of stock-out events happened
9. Total number of days stocked out
10. Total issued (Most recent 6 months)
11. Is there any expired product available in stock? If any, how many in units?
12. What is the total average monthly consumption of the product by the lower level (Lower level for Main hub are the regional hubs, Lower level for the regional hubs are health facilities)
13. What is your; Maximum and maximum months of stock? If you don't have any apply any such inventory policy, do you think you are overstocked of this product?

Note: For any product that experienced a stock-out in the last six months, please note reasons (by product).

	Product	Units of Count	Unit Cost	Available in Stock? (Y/N)	Product Expiry Date	Balance (Bin-card or HCMIS)	Stock-out most recent 6 months (Y/N)	Number of stock-outs within the year	Total number of days stocked out	Total issued (Most recent 6 months)	Availability of expired product (Y/N)	Product consumption by lower level (average monthly)	Stock policy (Min, Max)
	1	2	3	4	5	6	7	8	9	10	11	12	13
1	Nifedipine 20mg tablet	20x10											
2	Insulin zinc suspension 100IU/ml injection	Vial											
3	Chloramphenicol Sodium Succinate 1gm injection	Ampoule											
4	Erythromycin (as Stearate) tablet - 250 mg, 500mg	100x10											
5	Gauze Surgical 90cmx100 m mesh size 19x15	Roll											
6	Surgical gloves sterile latex No. 7.5	100											
7	T.A.T. 1500IU/ml injection	Ampoule											
8	Cimetidine 200mg/ml, 2ml injection	Vial											
9	Cotrimoxazol Suspension 240mg/5ml	240mg/5ml											
10	Amoxicillin 250mg,500mg tablet	100x10											
11	Ciprofloxacin 500mg Tablet	100x10											
12	Lamivudine 300mg/Tenofovir 300mg/Efavirenz 600mg Tablet	Bottle											
13	Zidovudine 300mg/Lamivudine 150mg/Nevirapine 200mg Tablet	Bottle											
14	RHZE (150mg+75mg+400mg+275mg) , RH- (150mg+75mg)	24x28											
15	Artemether + lumefanthrine (20 +120)mg	30											
16	Medroxyprogesterone acetate 150mg/ml injection	Vial											

Annex 8.0
SCV solution scorecard grading metrics

1.0 Sensitivity Grading

Score	Description
0	No data is captured to support the target business decision.
1	Some relevant data is captured, but it is incomplete.
2	All data is captured but the accuracy of the data is unknown or known to be low.
3	Data is complete and consistently biased (i.e. low quality but predictable).
4	All data needed to support the decision is captured, complete, consistent, and measurably high in accuracy.

2.0 Accessibility Grading

Score	Description
0	Data remains in the capturing systems with no attempt to integrate the data for later use.
1	Data remains in the capturing systems, but processes allow them to be manually integrated for ad-hoc tasks.
2	The solution integrates all the decision-relevant data, but not all of it is retrievable by decision makers.
3	Data is integrated and available to the decision maker, but not using the methods they prefer.
4	All relevant data is integrated and accessible by any relevant path the decision maker could use.
5	All relevant data is integrated, accessible, and the approach to integrating data is easily adapted.
6	All relevant data is integrated, accessible, and the integration approach is self-updating when confronting new data types or sources.

3.0 Intelligence Grading

Score	Description
0	There is no automated recognition from the solution that a business decision is needed.
1	Sometimes there is recognition from the solution that a business decision is needed.
2	The solution always knows that the business decision is needed.
3	The solution's approach to recognizing the need for a business decision is easily updated by users.
4	The solution's approach to recognizing the need for a business decision is self-updating.

4.0 Decision relevance Grading

Score	Description
0	The solution has no explicit input to this business decision.
1	The solution is a required information source for the decision maker. A user decides how and when to make the decision.
2	The solution is a required information source for the decision maker. The solution decides when the decision is taken and the user decides everything else.
3	The solution offers a set of action alternatives based on the event, or
4	narrows the selection down to a few, or
5	suggests one action, and
6	executes that suggestion if the human approves, or
7	allows the human a restricted time to veto before automatic execution, or
8	executes automatically, then necessarily informs the human, or
9	informs the human only if asked, or
10	The solution decides everything and acts autonomously, with no notice given to humans except for debugging.

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