

# Optimizing the Immunization Supply Chain in Sudan

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Abstract

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This study is looking to overcome traditional problems facing immunization supply chain system in Sudan for decades, such as weak dry supply chain capacity, inadequate warehousing and storage level, un-effective distribution at lower level, weak maintenance of the cold chain equipment, and weak logistics information system and data collection. Despite, the huge efforts exerted by concern partners to overcome those problems but still the outcome is far beyond the expectation of clients and patients.

This thesis report is based on that situation analysis where by bottlenecks and gaps were been identified and their magnitude quantified. The problems have been analyzed and the part which can be solved through modeling and redesigning approach have been selected. Additionally, different models are presented to allow transformation and changes in the traditional model that the EPI supply used since its establishment.

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<b>List of Abbreviations</b>	
AD Syringe	Auto disabled syringe
CO	Cooperative partner
CN&CD	Non-communicable and communicable diseases
CMS	Central medical supply
DHIS	District health information system
DTP	Diphtheria, tetanus, and pertussis vaccine
EPI	Expanded Program on Immunization
EVM	Effective vaccines management
FMOH	Federal Ministry of Health
GF	Global Fund
GDP	Gross National Product
GAVI	Vaccine Alliance
GSP	Good storage practice
HIV	Human Immune Deficiency virus
HSS	Health system strengthening
ISC	Immunization Supply Chain
LMIS	Logistic Management Information System
NMSF	National Medical Supply Fund
NMBP	National Medicines and poisons board
NHIF	National Health Insurance Fund
PHC	Primary health care
SMSF	State Medical Supply Fund
TB	Tuberculosis
MDR	Microbial drugs resistance
UNICEF	United Nations International Children's Emergency Fund
UNDP	United Nations Development Program
UNFPA	United Nations Population Fund

WHO	World Health Organization
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## Executive Summary

The National Immunization Program, i.e., Expanded Program on Immunization (EPI), is considered to be one of the most successful programs of the Ministry of Health in Sudan. The immunization program is well thought out as a major driver for health system strengthening in delivering integrated health services at PHC and it operates as a vertical program and its supply chain component is integrated within the health program activities. Optimization and redesign of the immunization program is required to overcome several of its structural and operational related challenges. Adopting a modeling and redesign approach could increase the immunization program's efficiency, effectiveness, coordination and sustainability. This thesis report is based on that situation analysis whereby bottlenecks and gaps were identified and their magnitude quantified. Additionally, different models are presented and analyzed to allow transformation and changes in the traditional model that the EPI supply used since its establishment.

This study is focused on strengthening the current Immunization supply chain and explore the opportunities of making EPI and the National Medical Supply Fund (NMSF) to come together and increase coordination and identifying possible ways of sharing public resources and information. A goal of this thesis is to report on how to better define integration between these two entities. The analysis reports that the two entities, i.e., EPI and NMSF, are operating through a relatively similar administration structure. However, the NMSF has a robust presence in central and state level and has no existence at the local level and a weak presence at primary health care (PHC) level. EPI has a very strong presence at the local level and the PHC level. Additionally, community contribution of EPI is considered as the most successful factor in the Immunization program and any transformation in the system structure is designed to contribute to making this element stronger.

Technical evidence from this study shows that the Immunization Program can become more robust if it receives more engagement from NMSF's capacity and capabilities. Towards this end, findings indicated a willingness and readiness of the two entities' leadership and management to coordinate and share information and resources. Even though, NMSF is building its capacity at central and state level, the current capacity still associated with the constrained and struggle to meet the need of the NMSF'S Medicines and Supplies and the integrated programs. Therefore, it is essential for NMSF to deliberate its role in order to provide capacity development for all health programs, including the immunization program, by building strategically its capacity as required in infrastructure (e.g., warehouses and distribution), organization and human resources.

The local level is the most inefficient level in the immunization supply chain (ISC) that is in need of optimization. This could be achieved through a reduction in the number of cold storage sites per locality in the state capital and in the number of cold storages working days per month. When applying these proposals at the locality level, more than 40% of the operating cost can be saved.

The analysis showed that some of the challenges in the EPI supply chain can be addressed through coordination with NMSF. These include dry goods supply chain, maintenance of cold chain equipment, and human resources for supply chain capacity building.

The models proposed in this document require intensive discussion and analysis from all stakeholders at all levels to consider all factors related including technical, policy, administration, and enabling environment. Such an analysis is critical to the success of ensuring proper implementation. Eventually, EPI needs to select the most appropriate model(s) for application.

Below are the segments in ISC optimized and redesigned during this exercise:

- Dry supply chain capacity
- Warehousing and storage level
- Maintenance of the cold chain equipment
- Logistics information system and data collection

Below are the proposed models:

Models to support EPI-dry supply chain:

**Model 1.** This proposes full or partial integration with NMSF. This method is proposed to transfer the storage tasks of the EPI'S dry good supply chain to NMSF; based on a contractual arrangement between the two entities. In this case, EPI, would reimburse storage service to NMSF in accordance with the settled agreement. Tasks and responsibilities between the two entities should be made very clearly in the proposed agreement. The partial integration model is based on the current agreement and continues coordination between the EPI and NMSF to support EPI's dry supply chain through:

- I. Providing technical support to EPI's dry supply chain stores at central and state level by providing consultation to EPI management, and providing human capacity strengthening.
- II. Providing organization infrastructure supported by providing dry supply chain store equipment (e.g., ballets, ranks, air condition and furniture), store rehabilitation, and power supply equipment.

**Model 2** establishes or outsources stores for EPI at central and state level

Models to support maintenance of the cold chain equipment: The maintenance of cold chain equipment is addressed in this document within the holistic supply of the cold chain equipment; including item selection, specification, procurement and maintenance, guided by development of cold chain equipment technology framework or policy. Below are proposed models:

- (1) Optimize the current maintenance system
- (2) Outsource of the maintenance and spare parts provision
- (3) Support of NMSF maintenance workshops

Model to optimize cold chain storage capacity

(1) Optimize storage capacity at localities: Reduce number of cold room working days for 5 days only per month.

- (2) Optimizes storage capacity at localities: consolidate localities cold stores at state's capital
- (3) Optimizes storage capacity at localities: delete storage element at local level.

Model to optimize vaccine logistic information system: A mobile phone application is proposed to overcome most of information management-related challenges faced by EPI. Such a system would need to interface with EPI's Web based system. An application based on telecommunication companies is available in the country. Below is the model proposed:

- (1) Apply a mobile phone application at health facility (HF) level

Models to optimize vaccines distribution and transportation

- (1) Procure or outsource refrigerated vehicles
- (2) Apply a door to door delivery system
- (3) Supply Darfur states with vaccines every 4 months

Optimization and redesign of the immunization supply chain should be considered as a continuing process. This reform should lead to more optimization and improvement. Proposed is: optimizing cold chain storage at locality level and transfer cold rooms and refrigerators to state's main store that leads to increase in storage capacity at state's main store. Further reform could reduce the frequency of shipments per year from central to states in order to further improve the efficiency of the system.

## 1. INTRODUCTION

The supply chain for vaccines is considered as a key concern for the National Immunization program, i.e., Expanded Program on Immunization (EPI), and health sector in Sudan. EPI is one of the country's most successful health programs and well- thought out as a major driver of health system strengthening in delivering integrated health services at PHC. The EPI's program's supply chain system has a variety of health supplies as it targets a range of population and interventions. These include children in the age range from birth to 15 years, women of childbearing age and even the entire population such as during meningitis and yellow fever campaign. EPI also delivers vaccines containing 10 different antigens during routine activities in addition to different campaigns as part of the global initiatives such as polio eradication, measles and rubella eliminations and maternal and neonatal tetanus eliminations. EPI's vaccines are procured through the government of Sudan with contributions from cooperative partners namely UNICEF and GAVI. UNICEF presently procures the six basic vaccines and four new and underused vaccines through GAVI support.

Over decades, the EPI supply chain was exerting huge amounts of efforts focusing on the cold chain storage capacity as main element to ensure vaccines safety and potency. With the expansion in the EPI program mainly at the lower levels of care in 2012, the system was operating in 87 localities. In 2017 this jumped to 182 localities, and more recently, The Federal Ministry of Health (FMOH) implementing major structural reforms to integrate and expand the delivery of its PHC services to the entire population. This required additional health facilities to provide immunization services alongside of other PHC services.

This further increases the need for more effective unified immunization supply chain and ultimately unified Health Supply and Logistic System. With the rapid introduction of new vaccines this situation required to change the EPI's approach to deal the challenges facing cold supply chain. What is needed is a comprehensive, interlinked approach to operational, supply chain functions, infrastructure and human resources and storage equipment.

Over the years, partners have played significant roles in support of the vaccination supply chain in Sudan. UNICEF is the historic cooperative agent that has extended support to procure basic vaccines and provide technical support. GAVI supports the provision of under- accessed vaccines and financing for some elements in the operational plan and provides technical support. Development partners continue to work closely with the federal government of Sudan in its efforts to redesign and optimize ISC, aiming to improve ISC infrastructure and performance.

During the period 2001 - 2004, the EPI program had acquainted with advanced technologies for cold chain storage, vaccine stock management and temperature monitoring into the central cold

store. The Central Cold Store was certified by WHO and UNICEF in 2008, it obtained the certification standard with overall score of 94% for the 10-vaccine management global criteria's as the fourth country in EMRO to get this certificate. In 2009, it has awarded the award of excellence in vaccine stock management from GAVI.

EPI continues to prove intangible efforts to make advances in the immunization supply chain (ISC). However, enormous bottlenecks exist in performance and challenges in the system structure. Several factors account for these constraints including: lack of clear dry goods supply chain system, constraints in the maintenance of the cold chain equipment, challenges in delivery and distribution system at a lower level, issues related human resources for ISC, poor quality related to information management, lack of proper coordination with NMSF, and pressures in financing and resource mobilization.

These challenges demonstrate that advances and further development in ISC extends beyond the provision of the cold chain equipment. A holistic framework that addresses legal, policy, organizations, and structure related to an operational model and supply chain functions is an essential key factor to ensure ISC achieves its objectives and obligations towards the immunization program. These steps, in turn, can make vaccines more available at lower levels of care at the right time, quantity, cost and quality.

This thesis focused on strengthening the current ISC by proposing how to optimize the structure and organization of the immunization supply chain. To achieve this goal, an analysis was conducted of gaps and bottlenecks in its performance. This activity also explored the opportunity to achieve the benefits and advantage of the capacity and capability of the NMSF through greater coordination, integration, resources and information sharing and human capacity building to compensate gaps in ISC (Figure 1).

ISC redesign and optimization is a unique approach for the country of Sudan to address these deficiencies. It built upon performing change and transformation to the immunization supply chain, aiming to strengthen the system's capacity in order to increase efficiency, effectiveness, coordination, and sustainability. The situation analysis showed that EPI's ISC may experience a slight change, such as changing the delivery system from come and pick-up to door-to-door delivery mainly at a lower level. In addition, other elements consist of introducing refrigerated vehicles throughout the entire or portions of the health system levels, compile LMIS reports generated at health facilities (HFs), and changing responsibilities of local level supply chain staff.

Moreover, the situation analysis recommended some fundamental changes that affect system organization structure, such as integrating the dry goods supply chain and maintenance with NMSF, removing one level from the system administrative levels at the logistic side only, outsourcing to a third party to carry out one or more of the supply chain functions such as distribution or maintenance, and proposing the introduction of an electronic information system along with the introduction of the District Health Information Software (DHIS) at PHC level.

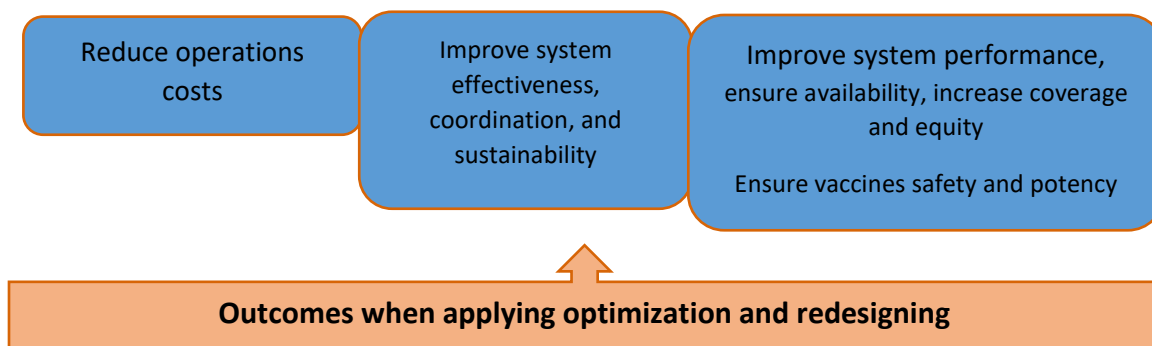


Figure 1. Illustration of the Immunization Program’s improved supply chain.

These changes are made based on the evidence created during situation analysis report, where, the main bottlenecked in performance and gap in the structure have been identified.

### 1.1 Purpose of the ISC Optimization

The purpose of this study is to strengthen and optimize the current ISC in Sudan including operations and infrastructure for dry and cold chain, within the national supply chain strengthening framework to address unification of some ISC elements, as necessary. These efforts are intended to contribute to ensuring ISC is energetic, flexible, effective in delivery, efficient in cost, well-coordinated and sustainable.

### 1.2 Objectives of the ISC optimization

- Identify ISC major bottlenecks and main gaps and provide opportunity to address them through system redesign and optimization.
- Provide restructuring and redesigning to the national immunization supply chain system based on optimization approach and provide platform for discussion, including:
  - I. Provide various models that could be used to solve out the deficiencies related to the current model of the supply chain functions as required (distribution and delivery, storage, maintenance, information system, human resources for supply chain, cold chain equipment, quality assurance.
  - II. Redesign supply chain management process as required namely related to distribution and inventory management.
  - III. Provide evidence and robust data to support the proposed model
  - IV. Discuss with all stakeholder related to immunization the proposed models and agree on the best model based on the evidence provided
  - V. Pilot the selected models in one or 2 states and extract the lessons for generalization to all states.
  - VI. Determine the elements of the ISC that might be strengthen through unification with the national supply chain system for public health commodities.

### 1.3 Scope of work

This effort focused on vaccines and their complementary supplies procured by the EPI and its affiliated organizations, such as UNICEF and GAVI, to address the national need for immunization of the target populations of the entire Country. The study focused on optimizing the current vertical immunization supply chain through redesigning approach. The study outcomes will be piloting in one or two states, lessons will be extracted, and the final accepted models will be applied in all states. Flexibility will be considered during implementation according to the local context of each state.

### 1.4 Demand for integration, coordination, and collaboration between national entities in supply chain

Generally, performance of the public health supply chain is weak in Sudan. The FMOH was committed to a plan of action that required integration of the procurement and supply chain functions in the sector to improve coordination, focus strategic directions and investments, maximize use of the scarred resources and enhance decision-making.

According to NMSF Act 2015, all national entities including health programs and other projects need to work in an integrated approach with the NMSF as it was set up as the national entity that would take the lead and responsibility for providing procurement and supply chain services up to the last mile. Integration does not mean taking over all supply chain responsibilities of health programs and put into the NMSF's basket. Rather, it means open channels of coordination and communication and identifying opportunities to share information, public resources, experience and capacity building and apply economies of scale. Different models of integration are available in a supply chain. For example, full integration is process of unify all supply chain functions with one national entity while partial integration is a process of integrate one or more of the supply chain functions with the main national entity. It is the decision of the program to determine while type and level of integrate to make, considering the purpose of the integration to increase efficiency, effectiveness, and sustainability. Adequate analysis need to be considered before commencing any sort of integration including analysis to the capacity, ability and objective of the integration.

### 1.5 Harmonizing and complementary of the optimization of the ISC to National Effective Vaccine Management (EVM) Improvement Plan to Strengthen the Immunization Supply Chain of (2017-2020)

The efforts to optimize and redesign the ISC are to comply with and harmonize with EPI's improvement plan is based on the facts and information raised during the EVM analysis conducted in 2016 (Table 1).

Supply chain segment addressed by the redesign and improvement plan	Foundation of the improvement plan	Foundation of the optimization and redesign approach
Improve cold chain storage capacity	Ensure all system levels are equipped by the high standard cold chain equipment	Optimize the current cold chain stores at all levels and organizations
Vaccines distribution	reform the distribution system for vaccines and supplies to a “pull” system based on bottom-up consumption information through the VSSM	Improve distribution system through increase community engagement at lower level; including: provision of compliant trucks and vaccines carriers
Maintenance for cold chain equipment	Strengthen maintenance system and conduct preventive maintenance	Link cold chain equipment selection with procurement, distribution per level, spare parts and maintenance, guided by development of cold chain technology frame work. Outsource private sector
Vaccine logistic information system	Expand the VSSM to the remaining states to ensure that the required vaccine management system (VMS) indicators are included and use the web base EMRO VSSM version	Expand the web based application to HF using mobile application as interface
Dry Chain	Not detailed in the improvement plan	Strengthen the EPI dry chain including stores infrastructure and equipment; explore options of integration with NMSF

Table 1. Key elements of the National Effective Vaccine Management (EVM) Improvement Plan (2016)

## 2. FIELD ANALYSIS

### 2.1 Methodology

#### 2.1.1 Redesign Approach

The gaps and the bottlenecks in the ISC have been investigated to determine which of them could be addressed through the remodeling and restructuring approach. Therefore, this approach is not intended to solve out all ISC shortcomings and problems. Rather, it is intended to complement the efforts of the various interventions implemented by the National Immunization Program and its CPs; such as National EVM Improvement Plan. The redesign approach adopted a participatory and discussion method for the collection and analysis of qualitative and quantitative data. Adequate information is provided as evidence based to support any suggested model and comparative analysis is provided as well, to compare between the current model and the proposed model.

#### 2.1.2 Quantitative Data

The study utilized existing reports from previous assessments, surveys and/or any related documents that provided quantitative data. These included Household Surveys (MICS **2014**), and EVM**2016**, EPI program statistics and administrative data. In addition, data related to supply chain information management in procurement plan, deliveries, stock and inventory, and data on consumption were used. Moreover, NMSF related documents were reviewed, including strategy documents **2016-2020**, assessments, reviews and evaluation reports.

#### 2.1.3 Desk Review

The study involved desk review of key documents related to immunization program and supply chain management. The country's health strategic plan and health policy and national immunization program strategy were reviewed. International experiences with the immunization supply chain and redesign documents were reviewed as well. This approach provided an in-depth understanding and information on EPI and UNICEF's vision and objective for the immunization supply chain to achieve the intended coverage and equity. Additionally, the desk review captured the efforts and contribution of EPI's collaborates works in addressing the needs for effective and efficient immunization supply chain. NMSF main documents were also consulted.

#### 2.1.4 Qualitative methods

Qualitative methods were used to obtain the opinions of the various project stakeholders through individual interviews with key stakeholders. These consisted of interviews with key personnel from EPI, NMSF, UNICEF, and EPI's state level and service providers. Since the redesign recognized the discussion and effective dialogue are essential in guiding all process; the qualitative data were considered as essential elements to assess the proposed models and structures.

## 2.2 ISC situation analysis

The situation of the immunization supply chain has been analyzed in 2017 by UNICEF in collaboration with EPI to understand the current situation, gaps and bottlenecks.

The situation analysis covered mainly: supply chain functions, operations model and system infrastructure (Figure 2).

- ✓ Organizations structure and policy
- ✓ Dry Chain Capacity
- ✓ Procurement
- ✓ Warehousing and storage system
- ✓ Distribution and delivery system
- ✓ Maintenance of the cold chain equipment
- ✓ Logistics information system and data collection
- ✓ Human resources for immunization supply chain
- ✓ Vaccines waste management
- ✓ Quality assurance

Figure 2. Pillars covered in the situational analysis.<sup>1</sup>

## 3. BACKGROUND

### 1. Country Context

#### 1.1 Geography

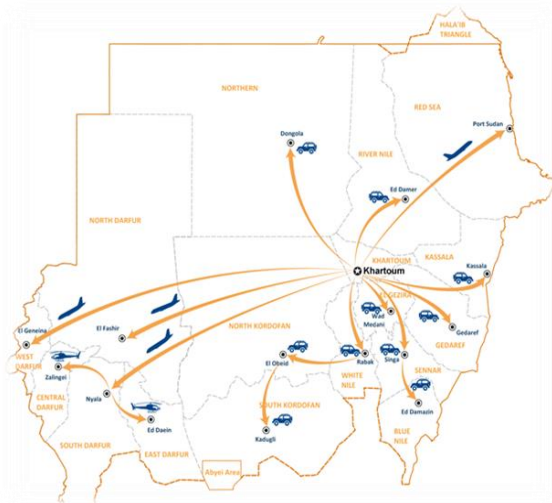


Figure 3. Supply chains in Sudan

<sup>1</sup> Immunization supply chain situational analysis, UNICEF, Sudan 2017

Sudan an eastern African country. It is the third largest country in Africa with land area of 1.8 million square kilometers. It is bordered by eight countries. Its land is mostly flat, with few mountains in northeast and west, while desert dominates the north.<sup>2</sup>Sudan's climate ranges between tropical in the south and dry desert to the north. The rainy season fluctuates moderate to heavy by region from April to November. Temperatures do not vary significantly with the season at any location and as regularly it reaches 48°C in the summer. The country's soils are various from sandy in the North, clay at central region, and laterite soils of the south. Sudan's geography and ecology contributes to the prevailing health, nutrition and population situation. Vast geographic areas, coupled with inadequate road and transport infrastructure affect coverage and accessibility of health services<sup>3</sup>. The geography of Sudan has an impact on the supply chain. The land is mostly flat that smooths movement of the health products from place to another, however, the land area is very large that makes a long distance and an increases in time to move from one health facility to another. The hot weather particularly during summer put huge challenges to the Immunization Supply Chain

The supply chain in Sudan is using two types of transport; land transport to most of the states and air transport to Darfur region (Figure 3). While train railways are cheapest method of transportation, they are no longer functioning, leading to increased cost of transportation and operational costs. S

## 1.2 Demography

Sudan's population is nearly 40 million people with crude birth rate 29.4 per 1000 of population; while fertility rate is at 5.7 per woman, the average household size is 5–6 persons, 88% of the total population are settled, including 32.7% in urban areas, while 8% are nomads, the annual growth rate is 2.53%. According to government figures, most 6.9% of the population is internally displaced 45.6% of the population is younger than 15 years including 16.4% under 5 years. Life expectancy at birth is 62/66 years male and female.<sup>4</sup>

## 1.3 Sudan Economy

Sudan's economy went through a fluctuating period in the last decade. It was growing fast until the second half of 2010 and experienced an average growth rate was in the range of 5-7% due to rise on oil production which counts for the largest resource of the national Income, in addition to the huge increase in oil price as well at that time. The gross domestic product (GDP) grew from USD9.9 billion in 1980 to USD66 billion in 2010. Basic economic, health and immunization indicators are presented in Table 3.

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<sup>2</sup>Central Intelligence Agency's The World Fact book (<https://www.cia.gov/library/publications/the-world-factbook/geos/as.html>)

<sup>3</sup>Central Intelligence Agency's The World Fact book (<https://www.cia.gov/library/publications/the-world-factbook/geos/as.html>)

<sup>4</sup>Sudan House Hold Survey 2010 (SHHS2)

However, Sudan went through bad economy situation after departure of South Sudan in 2011, when it lost 75% of its oil production which denoted 30% of the government revenues, in addition to reduction in oil price. A situation that led to economy collapse, increase inflation, high unemployment, poverty, unrest in some states and unequal distribution of wealth.<sup>5</sup>

Nevertheless, growth rate was projected to be 6% in 2016 and 2017, above the rate in 2015 which was 5%, and Inflation declined to 16.9% in 2015, due to relative stability, partial lifting of sections and increase investment in agriculture and livestock which considers essential to Sudan's economic diversification (away from oil) and could contribute to medium-term macroeconomic stability. While these sectors presently contribute approximately 35-40% of gross domestic product (GDP), they could contribute significantly more with greater investment and better governance.<sup>6</sup>

Indicator	Value	Year
Country GDP (USD)	63,997,129,027	2011
GDP per Capita (USD)	2120	2100
Total Expenditure on Health (THE) (US\$)	4,095,680,177	2011
Total expenditure on health as % of THE	6.4%	2011
General government expenditure on health as % of THE	28.9%	2009
Out-of-pocket expenditure on health as % of THE	69.88	2011
Donors expenditure on health	4.16%	2009
Total Government expenditure on immunizations as % of total government expenditure on health	1.4%	2013

Table 2. Basic economic, health and immunization indicators<sup>7</sup>

#### 1.4 Health situation and child health

The epidemiological profile of Sudan is dominated by malnutrition and communicable diseases. The main causes of morbidity and mortality are infectious and parasitic diseases, particularly malaria, tuberculosis, Schistosomiasis, diarrheal diseases, acute respiratory infections and protein-energy malnutrition. Non-communicable diseases (hypertension, diabetes, heart

<sup>5</sup>African Economic Outlook (AEO) 2016

<sup>6</sup>African Economic Outlook (AEO) 2016

<sup>7</sup> Information in the table is sourcing from, the national health information center FMOH 2013, and the world bank report 2015

disease, cancer, asthma) are now emerging as a public health problem, with changes in socio-economic and lifestyle conditions.

According to the Annual Statistical Report 2010 the most frequent causes of outpatient visit are malaria (12%), diseases of respiratory system (**8%**), pneumonia (8%), diarrhea and gastroenteritis (5%), acute tonsillitis (4%), disorders of urinary tract (4%), essential hypertension (3%), injuries (3%), and diabetes (3%).<sup>8</sup>

Conflict has been identified as one of the major impediments to progress resulting in diversion of resources earmarked for social-sector programs and unsatisfactory progress in implementation of some of the development projects. The Sudan Household Health Survey (SHHS, 2010) revealed that inequality in health outcomes, principally due to issues of access to health services, is among the major challenges facing progress to achieve better health outcomes.

### 1.5 Description of the public health supply chain in Sudan

NMSF is the main national entity mandated to provide procurement and supply chain management services to the public health sector. Unlike other vertical programs; EPI is completely vertical program while GF supported programs (HIV, TB and Malaria), RH, and NHIF are partially integrated within NMSF. The integration of these programs with NMSF is happening at logistic level (e.g., warehousing and distribution).

The prototype to the NMSF was the Central Medical Stores (CMS) which was established in **1991** as a semi-autonomous organization to make essential health products available, accessible and affordable, and also facilitate the selection, procurement and distribution of these pharmaceutical and health products to the public health sector. The CMS underwent through many reforms, the most recent one was in 2015, which led to the formation of the NMSF under a new Act of Parliament (the NMSF Act, **2015**). Bilateral agreement included in 2015 Act was for the use of the NMSF procurement and supply chain services by all Federal and SMOH health programs, and to date, sixteen States have signed except Khartoum and Al Gaziera. This agreement enables the NMSF to manage supply chain to public health programs at State level, through establishment of decentralized NMSF branches in each State. The SNMSF is under supervision of SMOH, who chairs the SNMSF administration board.

Part of the reform that resulted in the setting up of the NMSF, was the requirement for, PHC reform and the integration of vertical and fragmented program supply chains with the NMSF structure (HIV, TB, Malaria, under 5 medicines and emergency medicines), in order to gain from economies of scale that would result, and thereby reduce sector costs for procurement and supply chain services, and maximize the use of the national resources. The Global Fund- financed medicines and supplies were the first program supplies to be joined into the NMSF structure for

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<sup>8</sup>National Health Information Center FMOH 2013.

warehousing and distribution. This was followed up by the, Reproductive Health and Laboratory commodities.

NMSF efforts to optimize the supply chain structure is designed to bypass the Locality level and deliver directly to health facilities, unless the local context in the State requires to have the Locality as the basis for last mile delivery service this design is meant to provide system efficiency, effectiveness and reduction in stock holding at many locations.

SNMSF has its own dispensing outlets in major hospitals (pharmacies) to dispense the Cost Recovery medicines. The pharmacies are directly linked to the main warehouse at the State capital. Most of Locality health administration offices have small health commodity stores built with the support from the Global Fund in 2007, but these were mainly to store the Malaria commodities.

Below are the programs that are serviced by the NMSF and its branches at the States:

1. Cost recovery of medicines
2. Under 5 years' of age medicines
3. Emergency medicines and medical consumables
4. Antenatal care and family planning medicines
5. Malaria, TB, HIV/AIDS medicines
6. Laboratory reagents and consumables
7. Medical devices and equipment health facilities furniture (e.g. hospital beds)
8. Blood bank reagents and consumables
9. Renal dialysis medicines and consumables and medications for renal and liver transplantation
10. Oncology medicines

#### [1.6 Description of the immunization supply chain in Sudan](#)

EPI-ISC is a National vertical program established to provide immunization services to all people of Sudan, it is managed by MOH at federal and states level; the ISC is completely integrated with other EPI programs segments. The system consists of four levels (number of facilities are in parentheses):

1. Central vaccine store (1)
2. State vaccine stores (18)
3. Locality vaccine stores(182)
4. Health Facilities around (3750)(fixed and outreach)

The system is continuing and interlinking between all levels; and the vaccines cross all levels to reach beneficiaries. The system has a very strong level of coordination with international partners namely UNICEF and GAVI.

The system is equipped by cold supply equipment along the chain, a total of 10,986 pieces of equipment were listed of which 35 are cold-rooms, 3 freezer-rooms, 1,242 refrigerators, 228 freezers, 1,406 refrigerators with freezing compartment, 301 ice-pack freezers, 1,655 cold-boxes, 3,303 vaccine carriers, 2,027 ice-packs, 374 voltage regulators/voltage stabilizers, 154 stand-by generators and 258 transport vehicles.<sup>9</sup>

The system has stable structure; with frequent renewal of the cold chain equipment and it continues its geographic expansion to additional localities and health facilities. The last reform took place as part of a holistic reform to the PHC which immunization program is key player. The PHC reform aiming to expand health universal coverage. This project started in 2014 with a target to increase the coverage by services from 74% to 100% by 2020<sup>10</sup>, as sequences the fixed HF providing immunization services have increased and outreach and campaigns decrease; while 400 vaccines refrigerators have been procured. As part of the PHC integrated reform the vaccines services are uniformed with nutrition and therapeutic food particularly at services delivery points (Figure 4). Table 3 is a description of the vaccine schedule and coverage for Sudan.

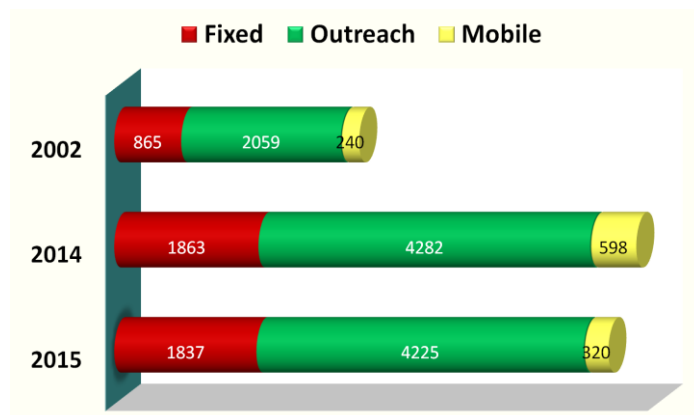


Figure 4. Antigens provided by EPI, number of doses per recipient, age group and coverage.

Sources: Joint Appraisal Report GAVI, EIP Khartoum 2015

<sup>9</sup>Inventories of Cold Chain Equipment Survey, EPI, Sudan 2017

<sup>10</sup> Joint Appraisal Report GAVI, EIP Khartoum 2015

Vaccines	Number doses of per recipient	Age group	Coverage (%)
BCG(lyophilized)	1	Under 1	95%
Measles(lyophilized)	2	9 and 18 months	70%
Penta (liquid)	3	Under 1	98%
Rota (liquid)	2	Under 1	95%
PCV(liquid)	3	Under 1	95%
IPV	1	Under 1	95%
Men A (lyophilized)	1	Under 1	90%
TT	2	Pregnant women	70%

Table 3. Vaccine schedule and coverage for Sudan

**4. MAJOR BOTTLENECKS AND GAPS IN ISC IN SUDAN**

The situation analysis displays the major bottlenecks in ISC performance and the gaps in the systems structures and organizations. The analysis is reported in accordance with the supply chain functions. The last mile is the most challenging level in the system due to lack of infrastructure (such as distribution, warehousing, power supply, and waste management), weak health management and administration, financial constraints, and interrupted human capacity building. To further illustrate the situation, the challenges were ranked as follows, in order of the most to the less challenging issues in Sudan ISC:

Constrains in:

- Dry chain storage capacity
- Maintenance of the cold chain equipment
- Distribution and delivery system at lower level
- Huma resources for immunization supply chain
- Logistics information system and data collection
- Cold chain equipment and Cold chain storage capacity
- Vaccines waste management

#### 4.1 Dry supply chain

The dry chain in vaccination includes the different types of syringes, safety boxes, equipment and spare parts necessary for the provision of immunization services. For decades, the focus was on the cold chain storage capacity and equipment, resulted in establishment of well-connected cold chain. However, dry chain was given less consideration leading to presence of disconnected system which lacks basic set-up and insufficient management. EVM 2013, 2016 and the EPI review reports that EPI-ISC lacks basic infrastructure for dry chain items at all levels, such as well-constructed stores, storage raking, air conditions, lighting, fire detection equipment, and power supply.

In most of the cases auto-disabled (AD) syringes are kept in places that are not clean, and not dry and with no proper ventilation. In some instances they are exposed to excessive heat or direct sunlight, such exposure will result in discoloring of the polythene and paper cover and destruction of portions sensitive to heat. Boxes containing syringes are placed directly on the floor, but on wooden or metal racks to avoid collection of moisture which will lead to infestation with fungi. The current condition of the EPI dry chain cannot ensure the insects may enter the boxes and damaging the covers that tend to affect sterility (Table 5).

Supply chain storage capacity	Major constraints
	Lack of stores for dry chain at all system levels, and current storage practice for fry chain is lacking basic infrastructure of good storage practice.
	Lack basic storage amenities such as power supply, air conditions, lighting, storage raking, etc.) at main stores and health facilities.
	At health facilities, good storage practice is not generally complied with for dry chain.
	Lack of store for dry chain at all system levels, and current storage practice for fry chain is lacking basic infrastructure of good storage practice.

Table 4. Supply chain storage capacity issues identified.

#### 4.2 Maintenance of the cold chain equipment

Lack of skilled engineers and technicians, workshops for maintenance with equipment and spare parts, clear capacity building plan, and high turnover are the most feature of constrains around maintenance of cold chain equipment by EPI. Furthermore, maintenance of the cold chain equipment specifically affected EPI, but other health programs in FMOH are not much better performing maintenance for medical and non-medical devices and equipment. This means it is problem facing the entire public health sector. In large part, challenges of maintenance started

with the product selection which required policy in technology and technology framework that guides selection of the right product according to the local context and environment.

Most of cold chain equipment breaking happens at localities and HFs level, and mainly for refrigerators. Most models of refrigerators are procured from the private sector and are not known and lack a local agent. In addition, suppliers are not engaged by a contract to continue providing the spare parts and after sale services. The situation is complicated at Darfur regions and remote areas where solar energy is the main source for power supply. Maintenance of these sophisticated solar energy systems add burden to the devastating region.

Maintenance results in intangible operational cost in EPI mainly at states level. This is in addition to the cost of maintenance, the transportation of devices to higher level to get advance service add extra financial burden. Further to that human resources in this area add challenges to the maintenance component, turnover is very high among Engineers and Technicians and the work environment is not attractive in terms of payment compare to the private sector or working overseas.

#### 4.3 Distribution and delivery system at lower level

Vaccines go through four administrative level before reaching clients, i.e., central, state, locality, and HF. The vaccines delivery system is similar in most of the states, i.e., the central level takes the responsibility to deliver up to states, and localities collect vaccines from the states. The methods of transportation are varying in the system; at HFs public transportation is the most common, which add burden to vaccinators at that fragile level. The vaccinators are responsible to collect the vaccines and to arrange for its delivery up to HF. The recent introduction of new vaccines increased the quantity of vaccines to be delivered to HFs. Consequently, it became more difficult for vaccinators at fixed HF to hold more than one vaccine carrier in public transportation (Table 5). Outreach vaccinators are also responsible to manage transportation. However, the amount of vaccine still small and could be carried on small vaccines carriers on public transportation. No refrigerated vehicles are found across the system; which consider as major gap in the vaccines delivery in the country.<sup>11</sup>

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<sup>11</sup> EVM EPI-Sudan 2016 draft report

Distribution and delivery system at lower level	<b>Major constraints</b>
	Distribution/ transportation is not instated in EPI-ISC, no clear system at lower level and no clear budget allocated for vaccines distribution at lower level.
	The system is lacking refrigerated vehicles along its level.
	Inadequate distribution fleet to match the expansion in EPI services at states level mainly, since States have on average between 1 trucks to manage EPI activities in the state
	The vaccinators are responsible to manage vaccines transportation at lower level mainly out fixed HFs, the situation that adds burden to vaccinators.
Roads infrastructure is very bad in some States like Darfur region, and adds a real barrier for good distribution practice	

Table 5. Major constraints in the distribution and delivery system at the lower level of care.

4.4 Human resources for immunization supply chain

It is recognized that ISC requires trained human resources to operate and manage this complex service. It also requires human resources from different professional backgrounds (e.g., pharmacists, health personnel, logistics, warehousing, communication, project management,), who are trained to function in a coordinated/collaborative and highly communicative framework, to ensure that the right vaccines are efficiently procured and delivered to the right service delivery point, through various channels, and arrive at the right time for use. Public health is the main professional predominant the EPI at states and localities; while Medical Assistants are majority at fixed HFs. Outreach which represents the mainstream of workforce in ISC and their back grounds are varying. The predominant of the workforces at lower level in terms of gender are females, in Al Gazeera state they represented 95% of the workforce

Bottlenecks related to human resources considered as one of the largest challenge facing the ISC by the EPI management at central and states levels. Because the scope of the EPI is narrow (9 vaccines in the list); the ISC contains 3 professional units:

- Supply and logistic
- M&E and LMIS
- Maintenance
- Store keepers

EPI invests considerable resources into staff development and capacity building; mainly with the introduction of new vaccines such as Rota 2011 and meningitis 2015. The trainings facilitated by senior EPI staff and central and state level and it is intended to provide the ISC staff with the essential requirement to handle the new vaccines. There is no clear training plan targeted ISC and based on staff need assessment and link with origination performance. The work environment at lower level is very challenging and lacking basic requirement like constructed well-furnished office for vaccinators, cardboard for registries and space for clients (Table 7). Staff turnover is common challenge facing EPI at all level and it is much larger among the senior management staff. In the last 3 years the EPI changed three General Managers; however, the turnover is lesser among the vaccinators at lower level.

Human resources for immunization supply chain	<b>Major constraints</b>
	Vaccinators across the ISC system often have inadequate or no training to prepare them for the logistics tasks they are expected to perform, particularly for the health personnel at lower system level.
	There is no clear job definition for vaccinators in FMOH RH system, and no job hierarchy and promotion from level to next upper level.
	High staff turnover and mobility among vaccinators and localities staff which creates a challenge for EPI in retaining trained and experienced staff along the supply chain operational points.
	Lack of capacity supportive tools and mechanisms like mentoring program, open dialogue discussion, guidelines, and toolkits
	Lack of training policy and plan in most of the States for supply chain capacity building program

Table 6. Constraints identified in human resources for the immunization supply chain

4.5 Logistics information system and data collection

The current practice shows that data is collected manually at all health facilities, compiled by Localities, who deliver data to State, and transfers such data to the central. Despite the fact that the system is manual but the EPI information system is very effective in provision of consistence data to high level for decision making and planning, and it is due to connected process in data collection and transfer and management is focused to ensure data is proceeding in time. The reports rate submission from states to central level is 100%in the last 2quarters.

The vaccine LMIS is not integrated with the EPI information related to health aspects like surveillance and morbidity data. The LMIS is collected at HFs using different formats and produce reports for vaccines consumed and request and other reports. The both reports compiled and

sent to states by locality. Information for expiry vaccines is reported separately. Stock cards are used at all level including health facilities.

Types of reports generated by the HF:

- Receiving of vaccines report
- Monthly report (consumption report)
- Request for vaccines
- Stock out report
- Report on equipment break
- Report on temperature measurement

In addition, vaccinators at HF required to fill the client’s information sheet, daily registry sheet and the stock card.

The real time data capture of the EPI is very effective, despite the monthly report which considers short time to send data from outreach to central level. The monthly meeting of vaccinators at locality to review and present progress the monthly report per HF, is supporting data management and processing. Despite the efforts, there are challenged remaining that need to be overcome; these challenges are related to data quality, and accuracy mainly at outreach level (Table 7).

Logistics information system and data collection	<b>Major constraints</b>
	Manual collection of data at health facilities is the norm, with resultant increase in staff workload, and affects data quality.
	A suitable electronic system for managing inventory, is not yet available at states and localities.

Table 7. Constraints identified in the logistics information system and in data collection

#### 4.6 Cold chain equipment and cold chain storage capacity

The EPI supply chain system keeps four levels of storage capacity, namely cold rooms at central level, cold rooms and refrigerators at state level, mostly refrigerators at the local level, and refrigerators at HF level and vaccines carriers at outreach. The cold chain storage capacity is varying among the system level. The central level capacity is approximately 69,400 liters at +5°C and 8,333 liters at -15°C <sup>12</sup> and it is not adequate comparing to the required amount needed per fully immunized person (433.31) cm<sup>3</sup> at +5°C and 8.4 cm<sup>3</sup> at -15°C ) as shown in Figure 5.

<sup>12</sup>Inventories of Cold Chain Equipment Survey, EPI, Sudan 2017

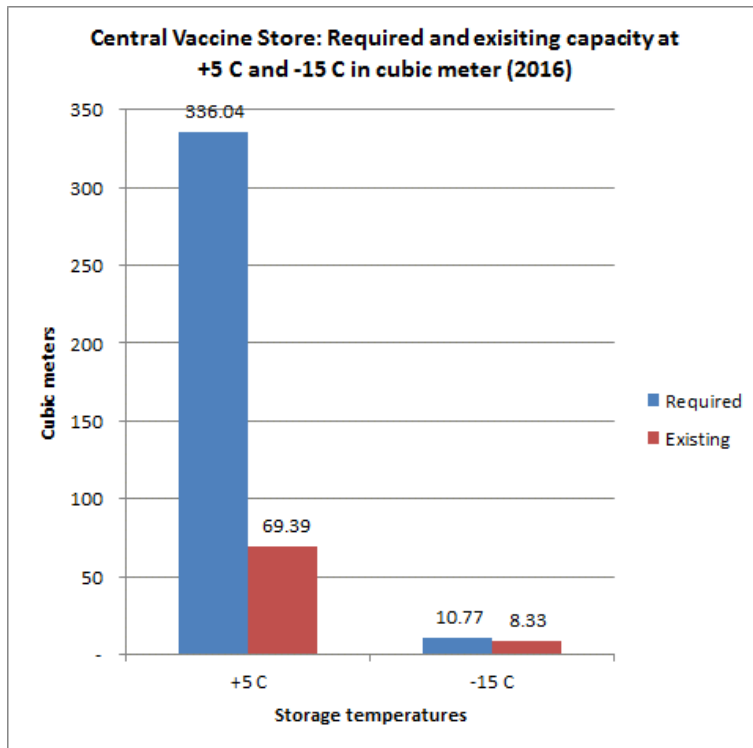


Figure 5. Central vaccine store required and existing capacity for cold chain

The central level warehouse making adjustments to manage the inventory according to the available storage capacity:

1. Staggering the consignments mainly for the campaigns and routine vaccines as well.
2. Quick delivery for vaccines for campaigns and the National Immunization Day after arrival the central warehouse.
3. Provide pack-up in case the central warehouse receives extra quantity

The cold chain capacity at state level is quite adequate comparing to the current capacity needed, except for Khartoum and AL Gazeira, and when the distribution frequency considers, which is a monthly supply. It is obvious that the locality level which is intermediate between state main store and HF, playing as distribution point rather than storage level. In all states 2 to 3 localities are based on state capital, which in average 5 Km far from the state main store. Optimizing the stores to be integrate with main store is required (Table 8).

The system is keeping the locality storage (distribution point) for the below reason:

- Geographic location of most of the localities which are far from the state main store
- Deficiency in distribution capacity at state level

Logistics information system and data collection	<b>Major constraints</b>
	The cold chain storage capacity is not adequate mainly at central level.
	The storage at localities level is not optimized; mainly for the localities exist at the state capital
	The localities store operate at inefficiency and effective manner, and vaccines stay less than 5 days at localities store before move to HFs and the rest 25 days there is no stock or small stock is stored.

Table 8. Constraints in the logistics information system and data collection for cold chain.

**5. REDESIGN OF IMMUNIZATION SUPPLY CHAIN: ANALYSIS OF MODELS**

This section explains various available models to overcome challenges and gaps in the EPI supply chain system.

**5.1. Models for dry supply chain**

The following proposed models are designed to overcome the current practice related challenges as described in the dry chain thematic area in this report.

**5.1.1. Model1: integrate EPI’s dry chain with NMSF**

This model is trying to solve out the EPI’s dry chain related challenges through applying different sorts of integration with NMSF. Since NMSF possess huge ability on dry chain as shown in the analysis; through continues process of building new warehouses and/or ability to design robust contract when outsourcing the private sector; EPI should get advantage of this privilege and make their warehouses comply with good storage practice for health products.

NMSF has adequate dry chain capacity and proper storage conditions, particularly at central level. NMSF dry chain area is expanding as due to the new modern warehouse constructed in 2017 and included more than 7000 m<sup>2</sup> and in volume it counts 49000 m<sup>3</sup>. In addition to the old stores that include more than 9000 m<sup>2</sup>. However, still the dry chain capacity at NMSF is constrained, particularly with integration of more programs. As shown in the analysis ISC dry chain includes mainly syringes and safety boxes and procured bi-annually. The dry chain capacity required by the EPI at central level is around 600 m<sup>2</sup> flat area with 6-meter height to provide volume of 3600 m<sup>3</sup>

This option is in alignment with the NMSF approach to support all vertical programs and implementation of the NMSF Act 2015 to support all public health medicines and health related products, as started by the Global Fund for HIV/AIDS, TB and Malaria and FP program where NMSF provided storage services for the dry chain to these programs based on agreement and obligation to be fulfilled by each program. As mentioned EPI'S dry chain may take different sorts of integration with NMSF as below:

- Full integration of EPI's dry chain with NMSF
- Partial integration with NMSF in dry chain

**Full integration:**

This method is to transfer the storage task of the EPI'S dry chain to NMSF; based on contract between the two entities. In this case EPI, will pay storage service from NMSF against settled agreement. Tasks and responsibilities between the two entities should be very clear in the contract. The experience of the GF supported programs (HIV, TB and Malaria) with NMSF in paying storage service is quite encouraging EPI to take the same steps.

Integrate EPI'S dry chain with NMSF, means transfer only the storage service at agreed level, and the other supply chain functions will remain with EPI. The approach of the dry chain integration of the EPI with NMSF should be started gradually and at central level only as first stage of integration. Second stage to be after 6 months and to integrate the state level and next to evaluating the experience of the central level and extract the lessons learned related to the challenges raised during implementation (Figure 6).

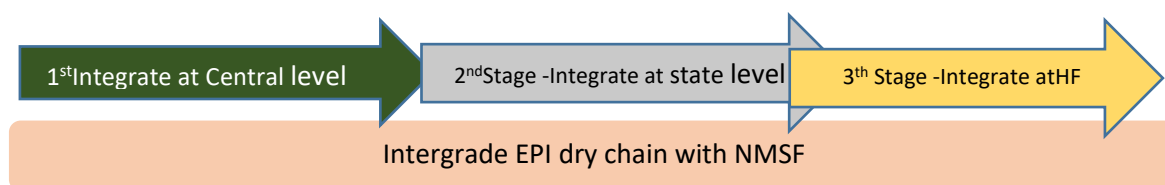


Figure 6. Integration of EPI dry supply chain with NMSF

## Partial integration

This model is based on the current agreement and continues coordination between the EPI and NMSF to include support EPI' dry chain through:

- III. Provide technical support to EPI's dry chain stores at central and state level by provide consultation to EPI management, and deliver human capacity building
- IV. Provide organization infrastructure support by provide dry chain store equipment (ballets, ranks, air condition and furniture), store re-habitation, and power supply equipment.

The two parties' obligations to support the model application are:

- Raise the coordination level between the two entities at high management level and advocate the integration among the policy makers to ensure gaining the adequate assistance to support the implementation process.
- FMOH should formulate technical committee including two entities and General Directorate of International Health to review all information related to the challenges of EPI in managing dry chain, proposed option in term integration model and time line, and the NMSF readiness to receive EPI dry chain at central level.
- NMSF to set up clear warehousing structure of the EPI dry chain including: inventory management, ordering process, communication process
- EPI to pay and compensate NMSF for storage services. NMSF is parastatal enterprise and however, it operates through non- commercial trend. The cost that will be paid by EPI is to cover the operational storage cost.
- The two entities to setup planning mechanism to plan for commodities receiving, storage, and distribution to state.

Challenges anticipated to this option are (Table 9):

- Lack of trust to the idea of integration between the government entities as method to increase efficiency, effectiveness, benefit of the economy of scale and secure the constrained government resources.
- Unclear Setup of coordination mechanism to share information and plan for actions
- Constrained on NMSF dry chain capacity

Positive	Negative and risk
EPI's dry chain will improve; and ensure availability of good storage condition	NMSF will not willing to provide storage service to EPI; either because they experienced constrain in dry chain capacity or lacking financial support to accommodate EPI
Technical and economic efficiency will progress and dry chain will be handed by professional organization	NMSF is parastatal company working against cost recovery and provide quality service, so their cost might be high and put burden to EPI
Load of managing dry chain will be shifted from EPI that save EPI time, efforts and cost and make them focus on creating demand side	The poor coordination and information sharing between the two entities may affect severely activities implementation and create frustration
The quality and safety of EPI dry chain will be granted	Misunderstanding between the two entities make the model to be applicable at technical point of view and not applicable from managerial perspective.
	The challenges facing other programs that experienced integration with NMSF add barrier to EPI to be motivated to integrate with NMSF

Table 9. Positive, negative anticipated impact and risk associated with model

5.1.2. Option 2: establish stores for dry chain at central and state level

EPI to establish stores for dry chain at central and states level through using two methods:

- Using public resources and establish stores owned by the EPI
- Sensitize and then contract the private sector to establish stores comply with GSP

The analysis showed the EPI is outsourcing storage at central level, however, it is not complying with GSP. At state level the situation is varying some states have adequate capacity and need rehabilitation to make their stores matching the storage acceptable standard.

This option is based on the rejection of the first option and decision from the government to keep EPI-ISC vertical and provide long term investment to support EPI dry chain as such the ongoing efforts supporting EPI cold chain. Many Countries especially middle income Countries are accepting strengthening the vertical immunization program considering the overwhelming of introduction of new vaccines every year; it is expected the number of vaccines to jump to 270

vaccines and to be available in the global market by the end of 2017<sup>13</sup> . Additionally, Malaria vaccine is expected to be approved shortly, and once it gets approval, it will make dramatic change in the immunization program and ISC in special. These facts lead Sudan and developing Countries to think for cold chain transformation and huge expansion in recent future.

## 5.2. Models for maintenance of cold chain equipment

Basically, all models proposed below to support maintenance of the cold chain equipment require development of cold chain equipment technology or technology frame work for cold chain equipment. The aim of these documents is to establish foundation to connect maintenance with other cold chain equipment supply chain function such as:

- Item selection; policy document will define the technical (mechanical and electrical) and managerial specification (provision of local agent, guidelines for contracting) required for each equipment according to the local environment and private sector position.
- Procurement: the policy document will determine the region to procure from or the Countries per the technology matching with the National context.
- Distribution: the policy document will define the level of distribution per the types of cold chain equipment. Getting support from GAVI optimization platform might be useful in this regard.

FMOH has many successful experience in out-sourcing private sector services. C&NCD department is contracting transportation company called Kasi to collect TB-MDR samples from all states to central TB laboratory.

### 5.2.1. Optimize the current maintenance system

The strengthening of the current system can be achieved through overcome the bottlenecks and the gaps displayed in the situation analysis. Optimizing the current model to fulfill main 3 factors:

- Skilled labor (engineers and technicians)
- Availability of equipped workshop
- Availability of spare parts

When we consider the above factors we found that the availability of spare parts counts for the most constrain faced the maintenance system at EPI and most of the non-functioning equipment is because of lack of spare parts in the local market and private sector. Therefore, put mechanism of making spare parts to be available will solve out large portion of the problem. Spare part can be provided through below options:

- Out sourcing; through contract private sector
- Contract NMSF; through support from the Medical and Health equipment unit which has experience in procuring medical equipment to public entities

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<sup>13</sup>Design New Approaches to Optimize Immunization Systems, Bill & Melinda Foundation, <https://gcgh.grandchallenges.org>

- Communicate to the suppliers that have supplied EPI program and request them to appoint local agent to provide spare parts or contract them directly to provide spare part services to the Country.

The three above options are applicable; however, NMSF is more suitable to play this role, based on the mandate to support the National Health Programs and capacity to connect with suppliers and performing procurement. Outsourcing private sector is win-win game. Private sector is looking for making profit, so to be engaged it required increasing in equipment scale and amount and ensure continues and secured market.

For the maintenance workshop EPI needs to invest on rehabilitation of the workshop at central and state level through provision required equipment and machines.

Maintain skilled engineers and technicians to serve EPI requires holistic retention plan including; capacity building, well compensation and salary and creation supportive work environment

#### 5.2.2. Outsourcing maintenance and spare parts provision

The analysis showed that the private sector capacity is adequate to provide maintenance services for EPI cold chain equipment. Tens of commercial companies are providing maintenance services to the private sector cold chain equipment including companies specialized in maintenance of solar energy equipment. It is obvious; the cost component when contracting private sector will lead to increase on operational cost of the EPI compare to the previous cost; subsequently, the private sector charge is high. However, the effectiveness of maintenance and cold chain equipment validity will increase.

Elements to be consider when contracting private sector:

- The cost of maintenance will increase compare to the previous cost, and in another side effectiveness will increase
- The private capacity should be assessed and the suppliers to be evaluated according to the services provided.
- The contract with private should be designed well and all quality assurance and risk mitigation to be considered.
- The financial capacity of the EPI should be guaranteed to ensure sustainability

#### 5.2.3. Support NMSF maintenance workshops

This option might be considered by EPI in the recent future and it is based on the FMOH agreement with NMSF to be responsible about all health and medical equipment supply chain functions including: selection, procurement, distribution and maintenance. NMSF planned to open 5 workshop at states level to support the activity at lower level in addition to strengthen the central level workshop as well. EPI can get benefit of these strategic workshop, since it intended to serve all public health programs and projects including hospitals.

Adequate coordination and communication needs to be exerted to ensure inclusion of the EPI cold chain equipment within the maintenance and workshops structure and operation model.

The element of strengthen of these workshops is related to the provision to the service even for private sector to ensure financial sustainability and support the gap in the private sector Table 10).

Positive	Negative and risk
The EPI cold chain equipment maintenance system is improved	Cost of operating maintenance process may be increase compare to the current one
The maintenance will be address within the holistic cold chain equipment frame work including selection, specification, procurement and maintenance	Issues related to design and manage private sector and deviation form contract obligations
Cold chain policy frame work will guide the cold chain maintenance system	Poor coordination and information sharing between the EPI and NMSF may affect severely activities implementation and create frustration
Cost of the EPI'S maintenance system will be more efficient and effective	

Table 10. Positive, negative anticipated impact and risks in support of NMSF maintenance workshops.

### 5.3. Models to optimize cold storage level

The analysis showed the main challenges related to storage capacity found in central and locality level. It is not adequate at central level, and additionally not efficient at localities. The EPI-ISC system is established over 4 levels and could be 5 levels when the outreach level counted, this consider as overwhelming structure and requires holding huge stock to fill all these levels at any point of time without interruption.

Keeping large number of storage level in the any supply chain system increases quantity stocked, subsequently increases procurement cost, increases risk of overstock and expiries, and increase overall operational cost.

However, the analysis showed the localities level is not working as storage level in all localities. It is distribution points rather than storage level. Considering the supply interval which is one month from state to locality and from locality to HF. That means once the vaccines arrived at locality store, the dispatching to HFs starts for maximum 5 days, leaves the cold room working as empty for the rest of the month. The cod chain storage capacity optimization is based on the below principles:

- Reduce number of administrative levels in the system as possible
- Reduce number of cold room working days when stock is running out or very minimum.

### 5.3.1. Models to optimize storage capacity at localities: Reduce the number of cold rooms working days when stock is running out or at a very minimum level

This model is based on the evidence that all localities keep vaccines stock for less than 5 days and keep the refrigerators and cold chain to operate with no stock in side or very minimum stock mainly belongs for HFs that experience delay in coming and picking up their quota. This model proposes that all localities to stop operating the cold chain at their level after dispatching vaccines to HFs and according to the current operation tradition in immunization program it is 5 days as maximum (Figure 7).

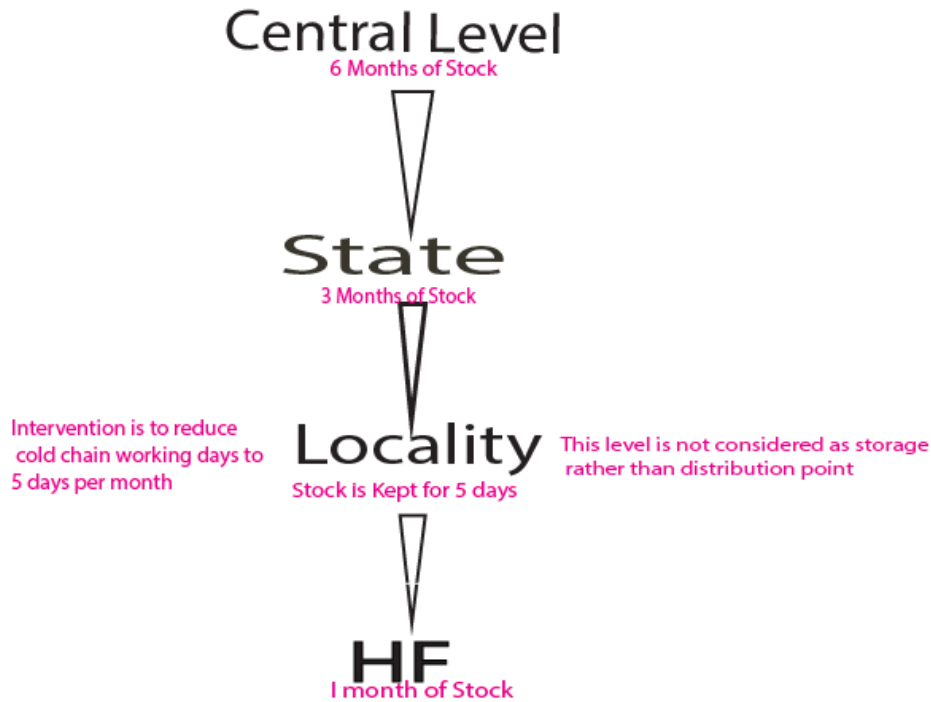


Figure 7. Models to optimize storage capacity at localities by reducing the number of cold room working days when stock is running out or at a very minimum level.

Below is the rationale of this model for the ISC-EPI program:

- Reduce operational model (energy consumption-electricity and fuel) and make saving in operational cost by average 1500SDG per locality.
- Reduce incidence of the cold chain equipment break (e.g., cold rooms, refrigerators, generators) by average 80% and subsequently reduce maintenance occurrence.

### 5.3.2. Model to optimize storage capacity at localities: Reduce number of administrative levels in the system

This model is built on the evidence that any state capital city hosts in average 3 locality offices and in total for all states around 54localities in numbers.For example, Algazeira state at capital city which is Madani, hosts Madani, Baraka and Ganoob Algazeira locality. Any of these 3 localities have cold chain equipment mainly cold rooms and getting monthly supply from state’s main store and waiting for the HFs to come and pick up their stock.

This model is proposed that these localities to consolidate and combine their cold chain capacity with the states’ main store to achieve the below advantage of the optimization (Figure 8):

- Increase cold storage capacity at state’s main store by adding the localities cold rooms or refrigerators and as explained in the above model that the cold rooms at localities are keeping stock for 5 days only. It is estimated around 20 L storage capacity will be added.
- Improve vaccines quality and safety, subsequently the storage conditions at state main store is better than at locality.
- Reduce operational cost by deducting the operational cost at those localities.

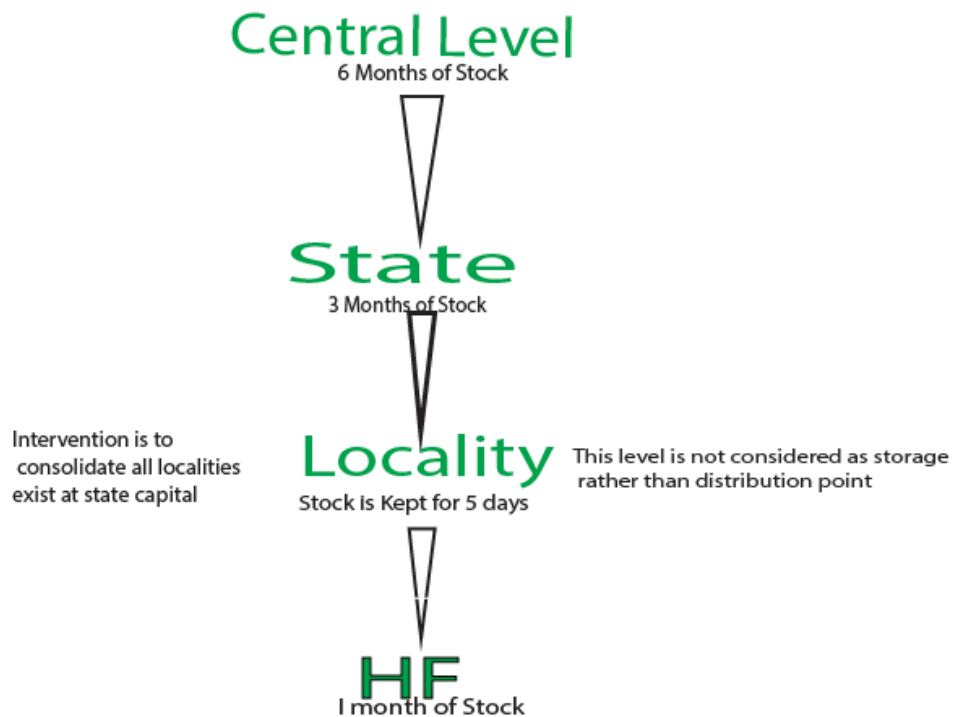


Figure 8. Model to optimize storage capacity at localities by reducing the number of administrative levels in the system

It is well-intentioned to note this model is proposing consolidate and unify storage part of the supply chain at locality and leaves the rest of the supply chain functions and program elements to operate at these localities. Therefore, the EPI program will continue keeping the locality as

program aspect only and to perform follow up, planning for distribution, supervision, training and all other program activities.

#### 5.3.3. Model to optimize storage capacity at localities: delete storage element at the local level.

This model is somewhat modified from the above mentioned one and proposes to supply HFs directly from state main store and bypass locality. The current number of fixed HFs entire the country is about 1873<sup>14</sup> providing immunization services. Therefore, 102 is the average of HFs per state which are possible to be supplied directly from state main store. This model will give EPI opportunity to focus in the storage capacity at state main store and HFs levels. This model is more suitable with some states. Requirement to apply this model (Figure 9):

- Provide adequate fleet of distribution through procurement of new vehicles or outsourcing private sector at state level according to the number of HFs per state and the geographical location of the HFs. Generally, the state's main store distance from HFs about 173 km in average.
- Application of the DDTU (i.e. the team topping up delivery); through provision of trained logisticians and program staff who fill vehicle with vaccines and move to the HF door and verify the records, check cold chain equipment and drop the required amount of vaccines.

Rationale for this model:

- Improve delivery system and apply door to door approach
- Make the transportation responsibility to be hold by the program rather than the current practice which is burden vaccinators
- Improve vaccine quality and safety through application DDTU method
- Reduce quantity of vaccine to be hold at supply chain system
- Reduce operational model

During situation analysis most of the staff visited did not recommending direct delivery from state to HF and their worries come from ambiguity related to resources provision to support the mode. Table 11 reports the positive, negative anticipated impact and risk associated with the model to optimize storage capacity at localities by deleting storage element at the local level.

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<sup>14</sup> Joint Appraisal Report GAVI, EIP Khartoum 2015

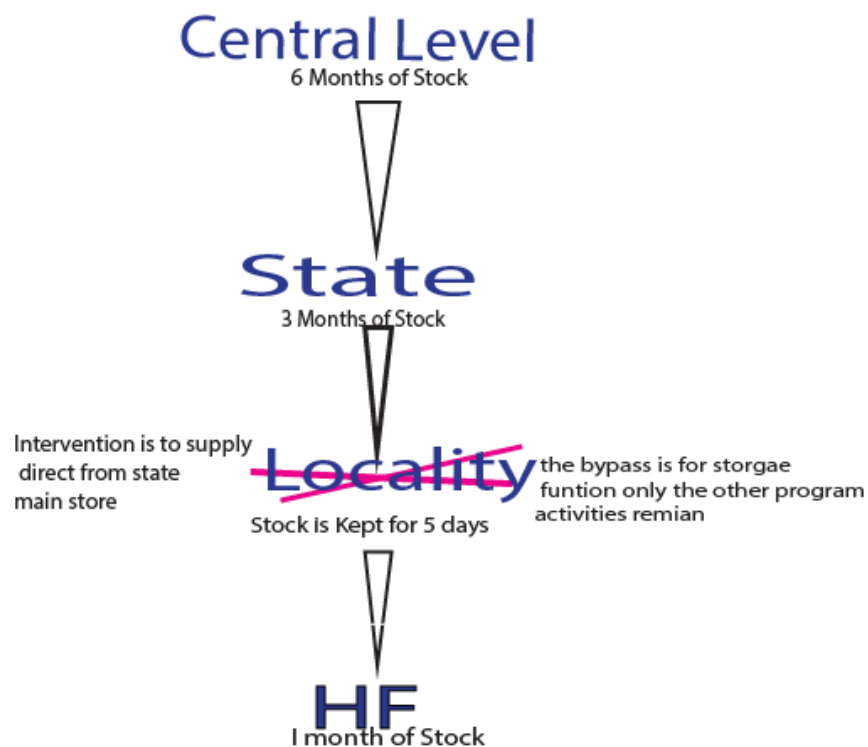


Figure 9. Model to optimize storage capacity at localities by deleting storage element at the local level.

Positive	Negative Impact & Risk
The EPI vaccines management efficiency and effectiveness will improve	Increase operational cost to manage emergencies orders; and may be the fast response to emergencies affected
Vaccines quality and safety will improve	Incidence of cold chain break may lead to increase amount of vaccines wastage
EPI overwhelming structure and levels will be reduced resulting in effectiveness and smooth delivery	The model application might affect other program activities like mobile centers and reporting system
Cold chain storage capacity will be increased at state level and that may lead to reduce frequency of shipments from central to state per year	

Table 11. Positive, negative anticipated impact and risk associated with the model to optimize storage capacity at localities by deleting storage element at the local level.

## 5.4. Model to optimize information system

### 5.4.1. Implement a mobile application at HFs

This model is proposed to support challenges related to the information management at last mile level (HF) where the information generated. Quality of the information is affected severely by the method of data collection at HF which is manual collection method based on paper. Intervention at this level will proof very positive impact on the information management and the EPI outcomes of coverage and equity largely. EPI proposed on the EVM improvement plan to expand the Web based to cover all states by 2021. Moving forward with this progress and implement mobile application at HF will contribute to strengthen information quality, accuracy and validity. Mobile phone is smart interface for WHO-EMRO Web base application which is selected by EPI in Sudan (Figure 10).

Mobile phones application is very easy to implement in terms of system design; and affordable cost, since the application is depending on phone telecommunication companies.<sup>15</sup> Sudan has telecommunication infrastructure that covers all parts of the Country including the remote areas. Application of the mobile phone application will support data collection, aggregation and processing at HF, managing vaccines stock, reduce losses and expiries, improve stock redistribution, reduce time of information delivery from lower to upper level and manage temperature information. Moreover, this application will contribute directly to improve EPI main outcomes related to actual number of child immunized and HF coverage.<sup>16</sup>

Mobile application has been implemented in many countries to support immunization information system and experiences of the countries demonstrate very positive impact of program's outcomes. In Sudan, NMSF is considering the mobile application as part of the national strategy element in supply chain.

Table 12 highlights the positive, negative anticipated impact and risk associated with use of mobile phone technology with the immunization supply chain.

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<sup>15</sup>MaciejSzymczak, Using Smartphones in Supply Chains, Management, ISSN 1429-9321, 2013, pp. 218-232

<sup>16</sup>Cisco Visual Networking Index: Global Mobile Data Forecast Update, 2014–2019, February 3rd 2015,

Figure 10. Illustration of a mobile phone based application for use within the immunization supply chain.



Positive	Negative and risk
Improve vaccines information management and ensure accuracy, validity and reliability of data	Mobile phone device may expose to loss and damage and needs efforts to be kept safe
Improve vaccines supply chain indicators related to consumption, stock and inventory management.	Unstable and interrupted internet supply may affect information delivery to upper level
Improve EPI program indicators of child immunized and HF coverage	Increase in operational cost to cover mobile application cost

Table 12. Positive, negative anticipated impact and risk associated with use of mobile phone technology with the immunization supply chain.

### 5.5. Models to optimize vaccines distribution and transportation

The major challenges identified during situation analysis related to this area are: the system is lacking refrigerated vehicles at all levels even the central level and lacking door to door delivery system. The distribution from localities to HFs is the most challenging point in the distribution system, when the vaccinators are holding the responsibility to transportation using different method mostly public transportation. With increase in vaccines numbers and volume this method of delivery becomes inapplicable.

#### 5.5.1 Procure or outsourcing refrigerated vehicles

This model proposes availability of refrigerated vehicles in all system level starting gradually from central level. Two methods are identified to implement this model:

- Out-sourcing: recently the private sector shows improving capacity in making refrigerated vehicles to be available and used for food and vegetables purposes.
- Procure refrigerated vehicles using EPI and CPs resources; this is more complicated process and it is not cost effective in the long run compare to outsourcing method<sup>17</sup>

#### 5.5.2 Apply door-to-door delivery system

A door-to-door delivery system is the optimum and best practice that the EPI program should work to achieve it. Delivery of vaccines is logistics process and it is EPI responsibility at all levels; vaccinators and health cadres should focus on provision of health care. This model proposes that EPI to put in place additional capacities to deliver vaccines from states to lower levels using door to door approach. Upper level should supply the next level in the system to its door.

<sup>17</sup> Report on Strengthening Distribution of Public Health Commodities, Axios Foundation and NMSF 2014.

### 5.5.3. Supply Darfur states every 4 months

The analysis showed that the cost of air shipment to Darfur states is very expensive and burden the EPI operational cost. The current practice is that the shipment to Darfur states (3 states the other 2 new states are getting by land from the old states) is frequenting every 3 months (4 times per year) similar to other states. This model is proposing to reduce the shipment to Darfur to be every 4 months (3 times per year) and to save the associated cost to support other program activities.

The main concern to this model is the capacity of the cold chain storage to hold stock for 4 months plus the buffer instead of 3 months with buffer. The analysis showed that the South Darfur has adequate capacity to hold stock for 4 months; while the other 2 states need to get more cold rooms to implement this model.

## 6. CONCLUSION

The optimizing immunization supply chain is most effective and cost effective way to address and solve the fundamental problems that facing cold chain in Sudan since decades. Structural and operational changes need to be made at lower levels mainly through modelling and optimizing the current system, coordination and collaboration between all partners engaging in cold chain is important to ensure transformation and system development, and NMSF should establish strategy to strengthen cold chain in short and long run.

## Annex 1, List of people and their agency and position who were interviewed

No	Name	Agency/position
	EPI Central	
1	Ikhlas Mohamed	EPI/ Manger
2	Samira Osman	EPI/ Cold chain manager
3	Fatima Ibrahim	EPI/ Consultant for cold chain
4	Salah Elagib	EPI/ stores supervisor
5	IsraElsadig	EPI/ supply manager
	UNICEF	
6	Shaza Ahmed	Health Specialist
7	KhattabObaid	Health Officer
8	Singe Pierre	Health manager
	WHO	
9	Immad Kuna	WHO/HSS
	EPI/ ALGaziera state	
10	KamilAlfadil	Program Deputy manger
11	Amir Seed Ahmed	WHO
12	Ahmed Mahgoob	Campaigns coordinator
13	AtigaAlrayah	Cold chain manager
14	Samahhassan	Routine and communication
15	MoheyAldin Hassan	Training Coordinator
	EPI/ ALGaziera state- Madani Locality	
16	Rabab Abdelmunim	Madani Locality
17	Aisha Himada	Madani Locality
18	Aza Bashir	Madani Locality
19	Kamala Abu Alhassan	Madani Locality
20	AalaAlbadri	Madani Locality
	EPI/ ALGaziera state- Madani locality- Barakat Health centre	
21	Nidal Mohamed	Vaccinator
22	Imman Mubarak	Vaccinator
23	HibbaHusien	Vaccinator
	EPI/ Khartoum State	
24	Ismail Aladani	State program manager
25	EPI/South Darfur	
26	Saadkhaleel	
27	Mubarak Mohamed	
28	Rabab Ahmed	WHO
	EPI/South Darfur- Nyala South Locality	
29	SalihAbaker Ahmed	EPI- Nyala South Locality
	EPI/South Darfur- Nyala South Locality	
30	Shadia Hassan	Vaccinator



## Annex 2- Terms of References

### PURPOSE

Under the general guidance of Chief of Health Section and the supervision of immunization specialist, and with close coordination with Expanded Program on Immunization and other health programs including health system strengthening unit, the consultant should design and reconfigured the component of the immunization supply chain and logistic system to optimize the current vertical systems into dynamic and flexible unified supply chain including, storing, management, transport, different levels interaction and relationship, data collection, utilization and staffing to create more efficient vaccine supply chain with focus on fitting different levels circumstances. The consultant should base his work in the previous evaluation and assessment that has been implemented, identified weakness, bottlenecks and the current programs capacities.

### Objectives:

1. To redesign a flexible, easy to monitor, simplified and unified supply chain (EPI dry store and NMFS supply chain) for health commodities based on the analysis of the current vertical supply chains and logistics that should meets WHO standard and fulfil the country specific needs.
2. Develop holistic and reliable supply and logistic strategic plan considering the new vaccines introductions, health emergencies, vaccine safety and in line with Gavi optimization platform requirements

### Major Duties and Responsibilities:

- Undertake desk review and interaction with programmes to assess the current vertically managed supply and logistic system within the ministry of health programs and its affiliated firms.
- Identify the major bottlenecks and constraints in the current supply and logistic systems with focus on immunization supply chain and National Medical Support Fund supply chain.
- Undertakes field visits to project sites at different levels when required.
- Keeps regular consultations with UNICEF and Ministry of health on the different scenarios of the unified supply system
- Based on modelling approach, the consultant should develop a unified supply chain and logistic system including a system for the supply management, outsourcing, procurement, storing and distribution of supplies to different levels with unified reporting and monitoring system; the proposed unified supply and logistic system should meets the following requirements:
  - (1) Should optimize the safety, reliability and efficiency of immunization supplies and other health commodities to meet WHO standard and national requirements
  - (2) Should be capable to satisfy the current and future expansion on the volume of supplies and prevent stock out the lower possible level
  - (3) Includes data collection from all levels of the supply chain to monitor performance and support evidence- based decision making.
  - (4) Cost effective and feasible system

- (5) Fulfils emergency stock and goods consolidation point in order to permit the rapid movement of supplies in emergency situation and campaign settings. Identifies training needs and develops training materials on unified supply management and logistic for government and other related staff
- (6) includes clear performance frame work and evaluation plan

**Other Duties and Responsibilities:**

The Consultant may be required to perform other duties within the scope of the job description in mutual discussion and agreement with the supervisor.

**Expected Deliverables:**

#	Expected Deliverable	Time frame	Comments
1	Situation analysis with key bottlenecks and constrains	By the end of second week	Should be discussed with key actors from FMoH and UNICEF for inputs
2	Final approval of situation analysis	By the end of week 2	Should be discussed with key actors from FMoH and UNICEF for approval
3	Drafted of the unified supply system	By the end of week 3	Review meeting with UNICEF and FMoHprogramme officers for their inputs
4	Submission of the first Draft of the unified supply and logistic system for review	By the end of week 4	Review committee
5	Refined the unified supply and logistic system	Week 5 and 6	Review committee
6	Final document of Unified supply and logistic system approved	Week 7	Review committee
7	Develop training materials and conduct the training for implementations	Week 7 and 8	The review committee will review the materials and approved the training schedule. Targeted states will arrange for training implementations
8	Small scale implementations of the unified supply and logistic system with close monitoring and follow-up	From week 9 to week 12 then monitoring will continue by EPI staff through the year	Under UNICEF and FMoH monitoring and support
9	Small scale evaluation and lessons learned	6 months after implementation	Will be carried out by UNICEF and MoH staff
10	Final report	Immediately in the last working day,	The consultant