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Evaluation of Cold Chain Equipment Platform Solar Fridges Project in Upper Nile State Republic of South Sudan

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Abstract

Background: A cold chain is a temperature-controlled supply chain with uninterrupted chain of activities that maintain a given temperature range that keep and maintain the quality of vaccines. Vaccines move through complex procedures and processes that require special attention and care. Effective cold chain systems require efficient end-to-end vaccine storage, handling, and stock management to maintain vaccines under strict temperature control of between 2 °C and 8 °C (for almost all vaccines).

Methods: A descriptive cross-sectional study design and mixed (qualitative and quantitative) research approach is employed to conducting the research. Data were collected through face to face in-depth interviews and questionnaires from Vaccinators and key persons from IPs. Prior to data collection, ethical approval was obtained from national Ministry of Health, Directorate of planning and M&E, and the University of Rwanda, Research Committee Board. Accordingly, data were collected after seeking the personal consent sought from the participants.

Results: The key findings from this study showed that the cold chain coverage has been improved compared to the result obtained in EPI coverage survey conducted in 2017. The results revealed that inadequate availability of EPI cold technicians, lack of fridge spare parts, trained staff, and adequate vaccine forecasting was the major challenges at county and the health facility level.

Conclusions: The main factor that contributed positively in strengthening vaccines supply chain system in the Upper Nile State was the substantive increase in cold chain coverage. However, the role of the CCEOP in improving immunization coverage is still doubted due to lack of regular preventive maintenance, spare parts, and EPI technicians. The major challenges that affect the vaccines relevance, effectiveness, efficiency and sustainability were found to be mainly poor vaccines handling, due to inadequate knowledge on cold chain management.

Keywords: CCEOP, Cold Chain, Fridge, Vaccine, Equipment, Optimization, Solar, Technician

List of abbreviations

CCEOP	cold chain equipment optimization platform
CCE	Cold Chain Equipment
BCG	Bacillus Chalmette–Guerin
GAVI	the Global Alliance for Vaccines and Immunization
IIP	Immunization In Practice
IPV	Inactivated polio vaccine
OPV	Oral polio vaccine

Penta	Pentavalent
Td	Tetanus & diphtheria
SDD	Solar Direct Derived
UNICEF	United Nation Children Fund's

1. Introduction

A cold chain is a temperature-controlled supply chain with uninterrupted chain of activities that maintain a given temperature range that keep and maintain the quality of vaccines (Australian government department of health, 2019). Vaccines move through complex procedures and processes that require special attention and care (Australian government department of health, 2019). Effective cold chain systems require efficient end-to-end vaccine storage, handling, and stock management to maintain vaccines under strict temperature control of between 2 °C and 8 °C for almost all vaccines (Australian government department of health, 2019; UNICEF Supply Department, 2018). Although cold chain equipment existed for decades, the equipment standard in many countries did not match with the pace of vaccine development and availability (UNICEF Supply Department, 2018). As evident the old cold chain technologies had issues and challenges such as poor temperature control, aging and underperforming and no longer considered optimal (UNICEF Supply Department, 2018). As a result to address the challenges, GAVI, in 2015, initiated and introduced, launched a new strategy to improve and strengthen the cold chain capacity and storage to increase access to the immunization services, to achieve better immunization equity and coverage in the targeted countries those under the GAVI support (GAVI, 2016). GAVI, through UNICEF allocated $250 million for implementation of the cold chain equipment optimization platform project (CCEOP) for 5 years running from 2017 to 2021 to upgrade the existing cold chain and to immunize an additional 300 million children, and equip 90,000 health facilities with the new Solar Direct Derived Refrigerators (SDD) (GAVI, 2016) .

UNICEF South Sudan had procured more than 260 new Solar fridges using GAVI and other donor funding sources to improve cold chain capacity at service delivery points to increase the access and utilization of immunization services in South Sudan (Anon, EPI coverage survey, 2017). UNICEF had been responding to the cold chain needs by replacing old refrigerators to ensure adequate cold chain storage capacity. The country applied for the CCEOP in September 2016 and the application was approved in March 2017 with actual implementation commenced in June 2017. Total of 123 SDD equipment were received in the country after the clearance, 84 SDD were successfully delivered to the health facilities countrywide as planned in phase 1, 77 SDD equipment were successfully installed, while 39 didn't reach to their expected last destination, and 7 remained un-installed. In phase 2, total of 82 SDD equipment were delivered to different health facilities, the out-sourced Premier Green (U) Company managed to install 19 SDD while 63 SDD remained uninstalled, 54 of them are in Upper Nile state are laying in the stores, November 2018 (UNICEF Supply Department, 2019).

The main challenges reported from the field include, inaccessibility due to poor roads networking, poor infrastructure, geographical terrain, communal fighting and armed conflict that broken-out in December 2013, and the still-ongoing crisis led to the large destruction of infrastructures, including looting, vandalization of cold chain equipment and generators, and lack of trained cold chain technicians with the irregular update of the cold chain inventory at the health facility level (UNICEF Supply Department, 2019). According to the EPI Coverage Survey conducted in 2017 in Republic of South Sudan. Report revealed that about 61% of mothers did not take their children for vaccinations due to long distances covered to reach the health facilities offering immunization services (Anon, South-Sudan-2018-EPI-Coverage-Survey-2017). Report confirmed that Upper Nile State is amongst the states with fewer health facilities with functional refrigerators (27%) and (77%) of health facilities with non-functional refrigerators (Anon, South-Sudan-2018-EPI-Coverage-Survey-2017). According to the assessment, 24% of the health facilities did not have vaccine refrigerators. A quarter of the health facilities had broken down fridges (non-functional) while the rest had fridges that were functional (49%), training of health workers on cold chain management was very low with Upper Nile having a mean of 2.5% (South Sudan EPI Vaccination Coverage Survey, 2017).

The state was selected because most of the planned and available procured CCEOP which were delivered to the state or at the county and health facility some of them were reported not installed, which is a serious challenge that may contribute negatively to the availability of potent vaccines and access to the immunization services, and many eligible target population remained un-reached or died due to vaccines preventable diseases. Therefore I would like to identify the factors preventing the installation and the management of cold chain equipment including the newly planned and procured and available CCEOP Fridges.

This study aims to assess the Cold chain Equipment Optimization Platform implementation status, progress made, management challenges in Upper Nile State, and suggest reliable strategies that will smooth the management of the Cold Chain Equipment including Optimization Platform. Hence, the study is designed to assess the progress made towards CCEOP implementation and to evaluate the effectiveness of the newly installed cold chain equipment, and examine the possible impact over the period from 2018 to 2021. The study aims to assess the role of CCEOP in strengthening vaccine supply chains system, the role in improving equity EPI coverage, and the role in improving vaccine's relevance, effectiveness, efficiency, outcomes, and sustainability of the investment made on Cold Chain Equipment.

2. Methodology

2.1 Study Design and Description of the Study Design

The study was conducted in Upper Nile State Republic of South Sudan, which is one of the 10 states in the country, based on the census conducted in 2008, Upper Nile State the has a projected population of 1,408,000 in 2021.The capital town is Malakal, covering an area of 77,823 square kilometres (30,048sq mi) under the leadership of the state governor. Most of the health services are rendered through the Non-Governmental Faith-Based Organization with minimal support from the government following the civil war which broke out in December 2013.

2.2 Study Design

A descriptive cross-sectional quantitative study design methods was utilized for this evaluation which included data collection from different sources: document review, direct interviews, health facilities assessments and review of health information logistics system. The researchers were able to collect information about CCEOP solar fridges, health infrastructure, management practices and cold chain management system in Upper Nile State. Since the approach is flexible with multiple variables that were used to capture a lot of information that could be useful for guiding the program management in the state. The design approach is appropriate because it is not expensive simple and does not require a lot of time and resources. The collected data under the variables will either approve/disapprove of the assumptions. The dependent variable under the study was CCEOP Solar fridges, whereas the independent variable includes, status of the newly received solar fridges, management practices and storage capacity to determine the effectiveness and equity distribution of the solar fridges in the state.

2.3 Population and Sample Size Determination and Sampling Techniques

The census sampling method was used for this study. This was due to small size of population of the study of those officers and Cold chain Technicians involved in the CCEOP management in the state. This method used the entire population as sample size. Therefore all the 79 Officers listed below were used as the study population sample. Kothari et al methods mentioned and explained that when this method is used for sampling, it provides highest accuracy level of confidence, as it leaves no element chance (Kothari, 2009). The method was preferred for this study due to the small population size. Officers were visited in their work place and the relevant data collection tools were used to collect the intended data from the participants**.**

2.4 Data Collection Procedure

Data were collected through in-depth interviews, researcher administered questionnaires to assess the health workers knowledge and practices, and health facilities cold chain status. COVID-19 prevention measures were applied and strictly followed during the interview and assessment. After obtaining the ethical approval from the Research Ethical Board committee, the ethical approval letter was shared in-advance with the local authorities state MOH and CHDs Official for further approval, data collectors were trained virtually at county level, and after that participant's in the targeted health facilities were informed prior to data collection on the purpose of the study to seek their consent and acceptance to participate in the study.

2.5 Data Processing and Analysis

On the receipt of the completed questionnaires, data cleaning was carried out to check, the errors in responses, inconsistency, omission, missing values, outliers, biases were carefully checked, for anonymity purposes, all questionnaires were coded and verified. Data was captured in MS-Excel windows 2013 and statistical package for social science SPSS (V-26) were utilized to analyze the gathered information from the various institutions. Descriptive statistics was used such to present the data such as, percentage, frequency, mean, and standard deviation.

3. Results

3.1 Demographic Information of the Respondents

Total of 48 health workers participated in the study at health facility level, in which 72.9% were male, and 27.1% were female. The age of the participants who participated in the study ranged between 26-35 (45%) and 36-45 (33%). Most of the participants are certificates holders (60.4%). And a total of 31 respondents at the county and the state level participated in the study of which 71% were male, and 29.0% were female, and 51.6% were having certificate, 31.3% with diploma, while only 8.3% had a bachelor degree.

Table 1. Demographic and human capacity information at state and county level

Variable N=(79)	**Category**	**State and county level**		**Health facility level**	
		Frequency	**Percentage**	**Frequency**	**Percentage**
Gender	Male	22	71.0 %	35	72.9 %
	Female	9	29.0 %	13	27.1%
Age of respondents	18-25 Years	2	6.5 %	9	18.8%
	26-35 Years	15	48.4 %	22	45.8%
	36-45 Years	12	38.7 %	16	33.3%
	45 Years and above	2	6.5 %	1	2.1%
Educational level	Certificate	16	51.6 %	29	60.4%
	Diploma	8	25.8 %	15	31.3%
	Bachelor degree	7	22.6 %	4	8.3%

Source: Own survey, 2021.

The result showed that, vaccines at the county and state level are managed by community health workers 15(33.1%) and Nurses 15(33.1). 77.1% and 68.8% of health workers received training on IIP and EVM. As a result, health workers are able to read and interpret temperature and demonstrate check test as shown in the below table.

Analysis of role of CCEOP in Increasing vaccines stock availability and potent vaccines at health facilities according to the plan (N = 48).

3.2 The Role of CCEOP Implementation in Strengthening Vaccine Supply Chains

Table 2. Assessment of the knowledge of health workers on cold chain monitoring

Variable N=(48)	**Category**	**Frequency**	**Percentage**
profession as Health worker in the health facility	Community health worker	15	31.3%
	Medical Assistant	4	8.3%
	Cold Chain Technician	1	2.1%
	Nurse	15	31.3%
	OTHERS	13	27.1%
Health worker are trained on simplified Immunization In Practice Manuel		37	77.1%
Health worker are trained on vaccine effective management		33	68.8%
Can you differentiate between the type of Antigens which is sensitive to heat or freeze		43	89.6%

Can you interpret temperature reading	40	83.3%
Can you correct placing temperature monitoring devices	35	72.9%
Do you know how to conduct check test	30	62.5%
Do you know how to interpret VVM	46	95.8%
Do you know what to do in case of emergency	28	58.3%
Health workers are oriented after the fridge installation and know how to do minor maintenance	37	77.1%

Source: Own survey, 2021.

From our findings, it was observed that 46 out of 48 health facilities are well equipped with CCEOP solar fridges while only 2, 4.2% health facilities didn't have any. It was also found that 46 health facilities out of 54 health facilities planned for CCEOP had received solar fridges 85.2% in the state.

Table 1. Availability of Solar fridge at health facility

Solar fridge	Frequency	Percentage
Available	46	95.8%
Not available	2	4.2%
Total	48	100%

Source: Own survey, 2021.

Data revealed that 96% of the allocated CCEOP solar fridges received were successfully installed and fully functional which were delivered in 2018. And only two were found not installed during the time of the study. This showed adequate numbers of functional solar fridges in the state, and they are positively contributing in strengthening the cold chain storage capacity.

Data revealed that 96% of the allocated CCEOP solar fridges received were successfully installed and are fully functional as it's shown in the below Figure 1.

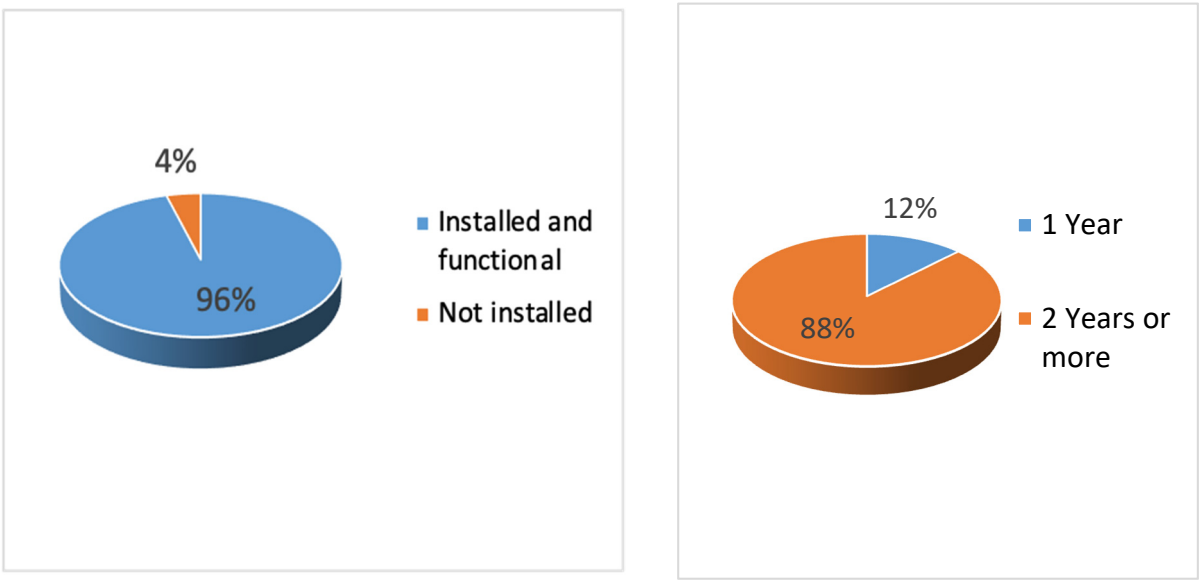

Figure 1. Showing the quantity of the fridges received during the period, installed, functional vs un-installed

Source: Own survey, 2021.

3.3 CCEOP Role in Increasing Immunization Coverage

Only 29.2% of health facilities had maintenance plan for newly installed solar fridges, while the majority of health facilities remained with no plan in place 70.8%.

Table 4. Status of maintenance plan at the health facility level

Category	Frequency	Percentage
Facilities with plan	14	29.2%
Facilities with no plan	34	70.8%
Total	48	100%

Source: Own survey, 2021.

It was also found that more than 69% of facilities visited didn't have cold chain technicians at state and county level with total lack of spare parts. However some minor preventive maintenance is being carried out by vaccinators for ¾ of visited facilities. Delay of installation of solar fridges could be partly attributed to inadequate availability of cold chain technicians although other factors should be further investigated as it's shown in the below table.

Table 5. Status of availability of solar fridge spare parts and maintenance services at the county and state level

Variable N=(31)	Category	Frequency	Percentage
Availability of cold chain technician	Available	9	31%
Availability of spare parts	Available	0	0%
Person in charge of maintenance	Cold chain assistants	8	25.8%
	EPI vaccinators	23	74.2%

Source: Own survey, 2021.

Results from Table 6 shows that 66.7% of health facilities have full time persons in-charge (Vaccinators and cold chain assistants) taking care of cold chain equipment and regularly ordering vaccines and other dry supplies, while 33.3% have no specific or assigned persons to take care of the newly installed cold chain equipment, and ordering

vaccine as it's in the below table.

Table 6. Availability of person in charge of cold chain equipment and ordering vaccines at the health facility

Availability of person N = (48)	Frequency	Percentage
Person available	32	66.7%
Not available	16	33.3%
Total	48	100%

Source: Own survey, 2021.

3.2 CCEOP in Vaccines Relevance, Effectiveness, Outcomes and Sustainability

When new consignments arrive at the storage points their details are checked and recorded, this step is to ensure that all the supplies are safe and valid, and feedback should be given upon the findings. However the key findings revealed that, 43 out of 48 Health workers checked the vaccine upon arrival and provided feedback on the status of the received supplies, while only 5 of them did not. This gives assurance for health workers adequate knowledge on what to do when new consignments are received as it's shown in the below table.

Table 7. Status of whether vaccines are checked up on receival and delivery

Status of vaccine checked up on recieval and delivery	Frequency	Percentage
Checked	43	89.6%
Not Checked	5	10.4%
Total	48	100%

Source: Own survey, 2021.

From of results, it was observed that 75% break down of the EPI fridges were reported while one incident which was not (25%) as it's shown in the below table.

Table 8. Status of the cold chain in terms of break down and incident reporting at HF

Is the case reported	Frequency	Percentage
Reported	3	75%
Not reported	1	25%
Total	4	100%

Source: Own survey, 2021.

However, it was found that 89.6% of exposed vials of vaccines were not marked as DO NOT USE in 43 out of 48 health facilities, while only 10.4 were marked DO NOT USE in five health facilities. This result showed that there is an inadequate knowledge of health workers on how to manage the exposed vaccines as it's shown in the below table.

Table 9. Status of the exposed vaccines whether they are labelled as "DO NOT USE" in the refrigerator or not

Status	Frequency	Percentage
Labelled	5	10.4%
Un labelled	43	89.6%
Total	48	100%

Source: Own survey, 2021.

In the Table 10. The knowledge of the health workers on, vaccine safeguarding, storage handling practices at the

health facility level was adequate and acceptable. Knowledge on vaccine handling (First expiry used 93.8, vaccine checked for expiry date 85.4%, damaged and expired vaccines are returned to county health department 60.4, and removed from the fridge 89.6). Vaccine storage (availability of Min/Max digital thermometer, fridge tag or a data logger 91.7%, vaccine are store in the middle 89.6). And knowledge on vaccine safeguarding (Temperature maintained in the recommended range 95.8%). However ordering vaccine based on the monthly target still a challenge at the health facility level. Only 60.4% of health facilities regularly ordered their vaccines based on the monthly target as it's shown in the below table.

Table 10. Vaccines safeguarding, storage, and handling practices at the health facility level

Variable N=(48)	Frequency	Percentage
Non-vaccines items stored in the fridge	7	14.6
FIRST TO EXPIRE, FIRST OUT" principle is used	45	93.8
Vaccines that will expire soonest are used first.	46	95.8
Vaccines are checked for EXPIRY dates at the beginning or end of every month	41	85.4
Expired vaccines are removed from the refrigerator	43	89.6
Damaged and expired vaccines are returned to county health department.	21	43.8
Vaccines are monthly ordered based on target population needs	29	60.4
temperature of the refrigerator is maintained between +2°C to +8°C	46	95.8
Vaccines are stored in the MIDDLE shelves of the refrigerator	43	89.6
Refrigerator is equipped with a Min/Max digital thermometer, fridge tag or a data logger	44	91.7
TEMPERATURE LOG" is posted on the refrigerator	44	91.7

Source: Own survey, 2021.

In the below table results shows that most frequent stock out occur for three antigens, BCG 29%, Measles 23% and IPV 17% as it's shown in the below table.

Table 11. Status of health facilities with vaccine stock out

Variable N=(48)	Frequency	Percentage
BCG	14	29%
OPV	2	4%
Penta	3	6%
IPV	8	17%
Measles	11	23%
Td	2	4%

Source: Own survey, 2021.

Proper vaccine storage and handling play a crucial role in protecting communities and individuals from vaccine preventable diseases. Data tools including vaccine control books are very important to monitor the stock, and commodity availability. In the Table 12 below, shows the use of control book was effective in 17 out of 48 health facilities. This result showed the gap in vaccines and dry supply monitoring and control at health facility level as shown in the below table.

Table 12. Vaccine control book availability and the use

Status	Frequency	Percentage
Available	17	35.4%
Not available	31	64.6%
Total	48	100%

Source: Own survey, 2021.

Standard operating procedures are very important at all levels, national to sub-national vaccine stores, it helps health workers to perform their day to day duties safely and consistently, by adhering to safety rules attached to every task. In this study, only 23 (47.9%) of health facilities were equipped with standard operation procedures, and while 25 health facilities remained with no standard operating procedures guidelines. And these may affect vaccine management practices at the health facility level as show in the below table.

Table 13. Status of availability of standard operation procedures

Status	Frequency	Percentage
Available	23	47.9%
Not available	25	52.1%
Total	48	100%

Source: Own survey, 2021.

Conditioned ice-packs should be used for transporting all vaccines from national to sub-national level, to maintain the temperature in the recommended range, and ensure all antigen are potent. In this study, 40 (83.3) respondents used conditioned ice-packs, and only 16.7% of health workers did not use the conditioned ice-packs for transporting vaccines for field or outreach sessions, and this is a good practice, as it's shown in the below table.

Table 2. Status of Conditioned ice-packs used for transporting vaccines as well as for out-reach session

Status	Frequency	Percentage
Using conditioned	40	83.3%
Not using conditioned	8	16.7%
Total	48	100%

Source: Own survey, 2021.

According to the country immunization policy, all opened vials from the outreach sessions should be discarded, and the reason is to avoid any issues related to un-potent vaccine. However, the result showed that most of the opened vails of OPV, IPV, Penta and Td vaccines, were returned to the EPI fridge after outreach sessions 66.7%, and Vaccinators continued to use them for next sessions as shown in the below table.

Table 15. Status of open Vials of OPV, Penta, TD and IPV returned to the fridge after out-reach sessions

Category	Frequency	Percentage
Returned	32	66.7%

Source: Own survey, 2021.

3.3 The Role of CCEOP in Increasing Vaccines Stock Availability and Potent Vaccines at Health Facilities

In descriptive data analysis, averages (mean) were calculated for each constructed in Likert scales, from Strongly Disagree=1 to strongly agree=5. The numbers entered into the SPSS version (V-26) which represent the weight, and the weighted average for the scales was calculated to understand the mean values. The scale values (4 in a 5-point Likert scale were divided by the number of values [5] to know the distance between the scales. According

to Alfarra, W.A, .2009) the expected period length is equal to 4/5 =0.80, which is used to calculate weighted averages.

The below table is the interpretation of the average categories (mean values) with the degree of agreement for each factor based on Alfarra, W.A., (2009) suggestion as a weighted average between the values (please refer to Table 2).

Table 16. Weighted average for 5-point Likert Scales

Weighted average	Result	Result interpretation
1.00 - 1.79	Strongly disagree	Very low
1.80 - 2.59	Disagree	Low
2.60 - 3.39	Neutral	Moderate
3.40 - 4.19	Agree	High
4.20 – 5.00	Strongly agree	Very high

Source: Alfarra, W.A, .2009.

Table 17. The role of CCEOP in Increasing vaccines stock availability and potent vaccines at health facilities according to the plan (N = 48)

Dimension	**Item**	**Mean**	**St. Deviation**
CCEOP role in strengthening vaccine supply chain	The role of Cold chain equipment optimization platform (CCEOP) in strengthening vaccine supply chain in terms of making solar fridges received, installed and functional in health facilities	4.08	1.541
	The role of Cold chain equipment optimization platform (CCEOP) in strengthening vaccine supply chain in terms of making solar fridges replaced in existing health facilities	3.46	1.383
	The role of Cold chain equipment optimization platform (CCEOP) in strengthening vaccine supply chain in terms of making existing health facilities and in new health facilities.	4.02	1.194
Grand mean for vaccines supply		3.85	0.279
CCEOP role in improving immunization equity and EPI coverage	The role of Cold chain equipment optimization platform (CCEOP) in strengthening vaccine supply chain in terms of availability of Maintenance plan	3.50	1.544
	The role of Cold chain equipment optimization platform (CCEOP) enhancing immunization equity and coverage through Accurate vaccine forecasting and distribution	3.92	1.200
Grand mean for immunization coverage		3.71	0.21
CCEOP role in vaccines relevance, effectiveness, outcomes and sustainability	The role of Cold chain equipment optimization platform (CCEOP) enhancing vaccines relevance, effectiveness, outcomes and sustainability through improved Improve maintenance	3.75	1.263
	The role of Cold chain equipment optimization platform (CCEOP) enhancing vaccines relevance, effectiveness, outcomes and sustainability through improved system /Procedures for monitoring and reporting progress is available.	3.92	1.252
	The role of Cold chain equipment optimization platform (CCEOP) enhancing vaccines relevance, effectiveness, outcomes and sustainability increased vaccines stock availability and potent vaccines at health facilities according to the plan	3.79	1.398
Grand mean for relevance, effectiveness, outcomes and sustainability		3.82	

Source: research data 2021.

4. Discussion

The aim of the study is to assess the role of CCEOP in strengthening vaccine supply chains system, the role in improving equity in EPI coverage, and the role in improving vaccine's relevance, effectiveness, efficiency, outcomes, and sustainability of the investment made on Cold Chain Equipment in Upper Nile state in Republic of South Sudan.

4.1 Role of Cold Chain Equipment Optimization Platform Project in Strengthening Vaccine Supply Chain

In this study, the results showed that there is an adequate number of pre-qualified CCEOP refrigerators deployed and installed in the public health facilities in the state, compared to the last result obtained in EPI coverage survey conducted in 2017, which revealed that only 27% of health facilities were found with functional cold chain facilities in Upper Nile state (South Sudan EPI Vaccination Coverage Survey, 2017). This results, however, is similar to the study conducted in North West of Cameroon (Yakum et al., 2015). This results, however, is significantly is slightly better than study conducted in the two regions of Western and Littoral (Nguefack, 2011).

This increased it might be articulated to, the increase in number of the cold chain equipment, received through CCEOP project.

The result obtained from this study revealed that the role played by the CCEOP in strengthening the vaccines supply chain with a group mean value of 3.85 has an influential positive contribution role which is similar to the study conducted in Kenya, Pakistan, and Guinea, which found out that, all the participants were satisfied with all the process including installation, fridges functionality, and availability (Thimothy, 2015).

Results revealed the majority of respondents agree on role of the newly installed solar fridges in strengthening vaccines supply chain system in terms of installation, functionality, and replacement was highly positive with a mean score of 4.08 and 4.02. This means most of the respondents agreed on the good role that is played by the CCEOP solar fridges and have a significant contribution in strengthening vaccines supply chain management with a group mean of 3.85. This result proves the influential role played by the CCEOP according to the weighted average result.

4.2 Role of Cold Chain Equipment Optimization Platform in Immunization Coverage.

Based on the results the, majority of respondents agreed on inadequate availability of the maintenance plans, EPI cold chain Technicians, and Solar fridge spare parts. The result shows that most of the vaccines handlers are certificate holders. Preventive maintenance is not regularly carried out at the health facility level. Results revealed that about 33.3% of health facilities have no specific assigned health workers to take care of the newly installed solar fridges and vaccine forecasting. This is similar to the study conducted in Ethiopia, Jimma Zone, which revealed the shortage of cold chain equipment, and lack of timely maintenance for cold chain equipment were among the main challenges explored by (Feyisa, 2021).

The result obtained in a published study mentioned the Cold chain maintenance and temperature monitoring is still a major challenge in developing countries (Feyisa, 2021). Lack of preventive maintenance plans and refrigerator spare parts is a factor that could result in delays in responding adequately to fridge break down and could affect their performance and reduce their life-cycle. Weak vaccines forecasting is another factor that could affect supply availability and lead to poor immunization coverage.

4.3 Role of Cold Chain Equipment Optimization Platform Project in Vaccines Relevance, Effectiveness, Outcomes, and Sustainability

According to the result obtained in this study, although the majority of the participants agreed on the positive role played by CCEOP in improving vaccines relevance, effectiveness, and sustainability with regard to CCE and vaccine handling and management with (mean score 3.82) table 3.3.2. But still there are a lot of issues to be addressed, following are the common key findings from the study:

The study identified some challenges in vaccines management and safety practices. This is similar to key findings from the study conducted in Cameroon (North West Region) (Yakum et al., 2015). These practices could be attributed to inadequate knowledge of health workers on vaccine handling practices. Proper vaccine storage and handling plays a critical role in protecting communities and individuals from vaccine-preventable diseases (Health, 2020). According to the country immunization policy, all opened vials that remained from the outreach sessions should be discarded. And this to avoid any issues related to vaccines safety and efficiency (WHO, 2015). However, the result showed that most of the opened and used vails of vaccines were returned to the EPI fridge after the outreach sessions 66.7%. This is the same problem documented by many Authors in different studies (Ebile Akoh et al., 2016; Robson, 2010). This upward and downward movement exposed vaccines to overheating and long

exposure to light which can damage the vaccines and handicap the Immunization program (Mugharbel & Al Wakeel, 2009). This situation is a big doubt about vaccinated children. A similar situation was observed in Cameroon in which more than half of children with measles were reported to have been vaccinated against measles (Nguefack, 2011). The results showed that the majority of health facilities had sufficient stocks of three out of six antigens, however, stock out of BCG, Measles, and IPV was the main challenge. And this is contradicting with the National Ministry of Health policy that ensures the constant availability of all essential supplies at the service delivery point including the vaccines (Nguefack, 2011).This also contradicts with the global routine immunization strategy, and practices to achieve global diseases prevention which says to control vaccine-preventable childhood diseases, by 2020 immunization supply chain management should ensure, the availability of the right products at the right quantities at the right time, to ensure children receive their vaccination without interruption on time and schedule (Nguefack, 2011).

Data monitoring tools including vaccine control books are very important to monitor the stock, and commodity availability levels (Mugharbel & Al Wakeel, 2009). A similar study which was conducted in Uganda revealed that having accurate stock cards available for each stock keeping at all levels is crucial in determining the stock level and reordering period (Okiria, Mwirumubi, & Mpaata, 2016). However, quantities dispensed, stock at hand, losses, and adjustment emerged as essential data to be reported on a regular basis, as recommended by USAID|DELIVER 2011 (USAID | DELIVER PROJECT 2009). However, for easy inventory control and visibility, it's very crucial to introduce, Excel-based cold chain tools. The system that designed to support activities such as tracking immunization coverage and managing stock levels.

Fridge temperature is being recorded and regularly monitored including the weekend days in 95.6% of health facilities with functional refrigerators. This is better compared to a study conducted in Cameroon, which found out vaccine storage temperature was recorded in 67% of health facilities with functional refrigerators (Ebile Akoh et al. 2016). Similarly to a study conducted in Ethiopia in 2000 found 53.3% had sufficient knowledge on recording fridge temperature within the recommended range (Bogale, Amhare, & Bogale, 2019).

Significant investment was made on strengthening vaccines supply chain management in the state, and that contributed positively in enhancing appropriate cold chain capacity and storage.

Although the CCEOP played a great role in increasing the cold coverage in the state, still a lot of issues need to be addressed e.g. lack of regular preventive maintenance, spare parts availability, and EPI technicians.

5. Conclusions

The study was carried out to assess the role of CCEOP implementation in strengthening the vaccine supply chain as well as the relevance, effectiveness, efficiency, outcomes, and sustainability of the investment made on Cold Chain Equipment using CCEOP in public health facilities in Upper Nile state. Based on the study findings the following conclusions were made:

The main factors contributed positively in strengthening vaccines supply chain system in the state is due to, the increase in cold chain equipment introduced by GAVI in the state. However, the role of the CCEOP in improving immunization coverage still doubting due to lack of regular preventive maintenance, spare parts availability, and EPI technicians. The major challenges affecting vaccines, relevance, effectiveness, efficiency and sustainability were poor vaccines handling, inadequate training of health workers, and commodity monitoring.

5.1 Limitations of the Study

The limitations of the study includes insecurity in some part of the state, poor road networking, language barriers, delays in receiving completed questionnares, poor network and internet connectivity are few among others which hinders the acheivement of the study objectives.

5.2 Recommendations

State Ministry of health may provide IIP and RED training to health workers at the county and health facility level.

UNICEF and State Ministry of Health need to provide training on preventive maintenance to vaccinators and Cold chain assistants.

Vaccinators and cold chain assistants should regularly monitor vaccines and supply consumption levels on daily basis, to ensure stock outs are prevented.

UNICEF should ensure the availability of solar fridge spare parts at county and state levels to ensure effectiveness of the newly installed solar fridges.

State Ministry of health and UNICEF to recruit and deploy EPI cold chain technicians in each county.

Regular supportive supervision by County health department staff & implementing partners,

Coaching and regular mentorship on vaccine management by state and county EPI staff to the health workers at the health facility level, to ensure vaccines are well handled.

Introduction of the electronic stock management system at State and lower level for stock visibility, and to avoid vaccines stock outs,

Improve vaccine utilization reporting system by introducing new and advanced reporting platforms that does not need Internet, E.g. LOGISTIMO platform

County and health facilities staff should order Vaccine and related dry supplies based on the target population, to ensure immunization coverage is sustained.

National Ministry of health and UNICEF to ensure all health facilities implementing EPI activities have hard copies of standard operating procedures.

5.3 Recommendation for Future Research

To conduct similar study in the remaining counties, to evaluate the effectiveness of newly installed CCEOP solar fridges, and measure their contributions in immunization equity and coverage. Conduct study on the above aforementioned recommendations to evaluate they role in improving the supply availability at all levels including the service delivery points.

Declarations

Ethical Approval

The ethical consideration was obtained from the national ministry of health, directorate of planning and M&E, and the University of Rwanda, Research Committee Board to ensure that the study do not cause any harm to participants. The information was confidentially kept for all participants who were involved in the study. All data were collected after seeking consent from the participants were free to withdraw at any point.

Approval and consent was given by:

University of Rwanda School of Medicine and Public Health

National Ministry of Health, Juba M&E department

Consent for Publication

Not applicable since there is no individual details in our results.

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Authors' Contributions

Paulo Okech designed the study, collected data and drafted the work.

Prof. Dr. Shiferaw Mitiku, substantively revised the work and Manuscript.

Dr. Kashi Carasso, substantively revised the work.

Jean D'amour, substantively revised the Manuscript.

Marie Jeanne Mukazayire, substantively revised the Manuscript.

Competing Interests Statement

The authors declare that there are no competing or potential conflicts of interest.

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Abbreviations, List O. F., Availability O. F. (n.d.).Immunization, Newborn Care, and After Delivery. *South Sudan EPI Vaccination Coverage Survey 2017*. 19.

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