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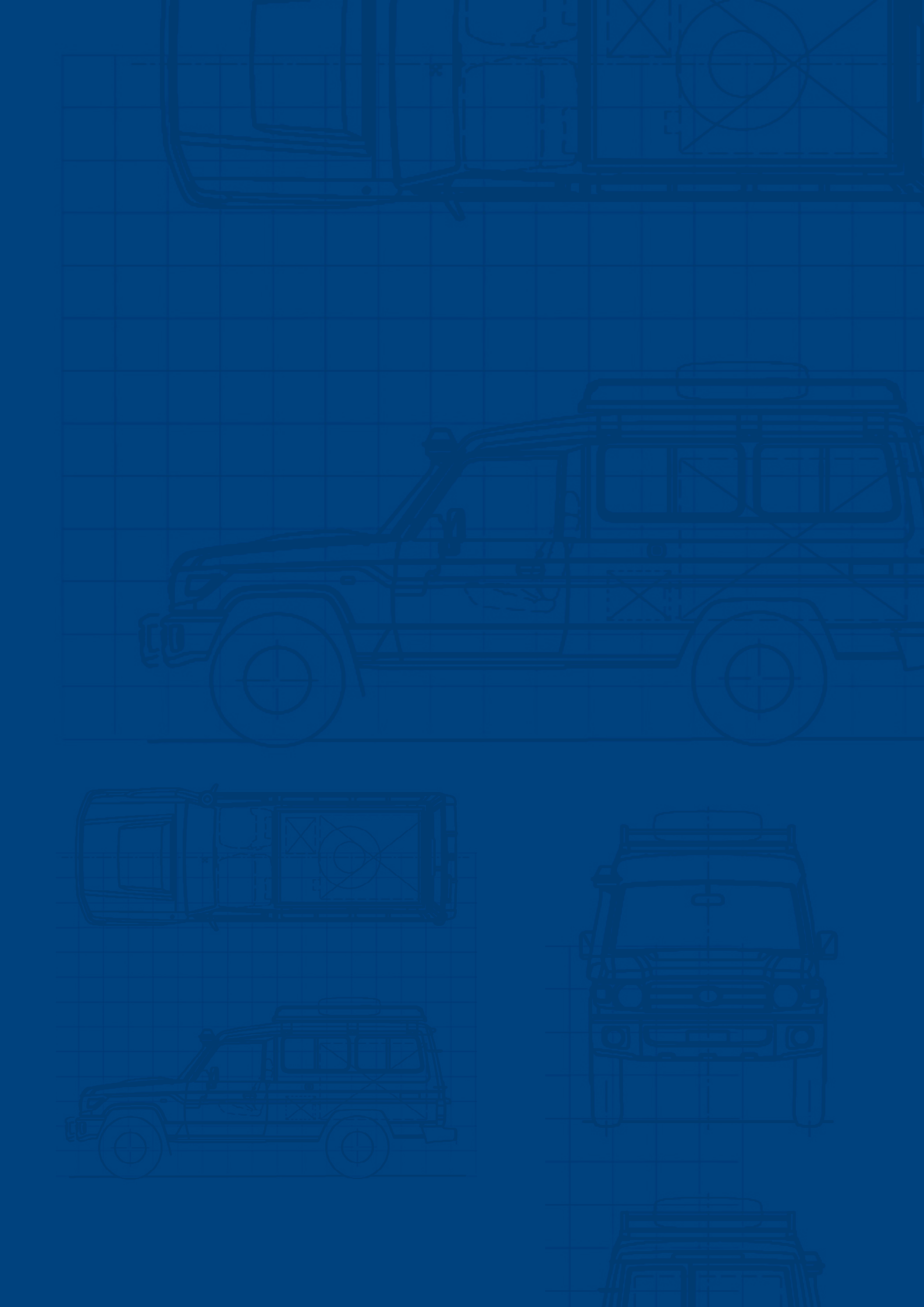
Evaluation Report of the Toyota Vaccine Land Cruiser

* Toyota Refrigerated Vaccine Transport Vehicle (WHO PQS E002)



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This external evaluation was commissioned by Gavi and conducted by two consultants, Othman Abubakar and Hugo Agostinho under the guidance of Yoshinobu Nagamine, Gavi. The views expressed in this report are those of the author, Othman Abubakar and do not necessarily reflect the views of the organization. The team is also indebted to the Supply Chain Expert, Maeve Magner for her valuable advice.

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Glossary

ACCESS Refers to the ease or difficulty in reaching certain locations based on geographical factors.

BASELINE METHOD The standard or previously existing method of operation used as a point of comparison.

BASELINE TRANSPORT COST The foundational cost used for comparisons, based on conventional vaccine transportation methods.

COLD CHAIN A temperature-controlled supply chain ensuring that vaccines remain within recommended temperature ranges from manufacturing to administration.

CONVENTIONAL VEHICLE A standard vehicle not specifically designed for vaccine transportation, used as a comparative baseline in this evaluation.

COST PER DOSE The total transport cost divided by the number of vaccine doses transported, providing a metric for cost-efficiency.

DISTRICT STORE The central storage facility within a district, where vaccines are kept before being distributed to health facilities.

DRY GOODS Non-perishable medical supplies and equipment that are essential for the storage, distribution, and administration of vaccines, that do not require specific temperature controlled environments.

EPI MANAGER Extended Program on Immunization Manager - responsible for overseeing vaccine programs and distributions in specific health facilities.

FUEL CONSUMPTION The amount of fuel a vehicle uses over a specific distance, relevant for calculating transport costs.

FUEL EFFICIENCY The distance a vehicle can travel per unit of fuel consumed, often a key factor in transport costs.

HEALTH FACILITY An establishment providing medical treatment and care to patients, including vaccination services.

IMMUNIZATION SUPPLY CHAIN The system of logistics and operations ensuring vaccines' journey from manufacturing to end-user, maintaining their efficacy.

MAINTENANCE AND REPAIRS Activities associated with keeping vehicles in operational condition, including both routine upkeep and fixing any damages.

MISSED COMMUNITIES Home to clusters of zero-dose and under-immunised children.

PULL SYSTEM A logistics model where health facilities proactively request and collect their vaccine supplies from a central location.

PUSH SYSTEM A logistics model where a central store distributes vaccines proactively to district stores or health facilities based on predetermined schedules or needs.

RAINY SEASON A period characterized by increased rainfall, which can impact transportation due to road conditions and other factors.

REGIONAL STORE The central storage facility within a region, where vaccines are kept before being distributed to district stores or directly to health facilities.

ROUTE OPTIMIZATION The process of determining the most cost-effective and efficient route for transportation.

TEMPERATURE MAINTENANCE The practice of ensuring vaccines are stored and transported within a specific temperature range to ensure efficacy.

TIME SPENT ON LOGISTICS The hours allocated by healthcare professionals, which can be impacted by logistical tasks such as vaccine transport.

VACCINE DOSE A specific quantity of a vaccine administered to provide immunity against a particular disease.

VACCINE LAND CRUISER (VLC) A specialized vehicle optimized for efficient transportation of vaccines while ensuring their quality and safety during transit.

ZERO DOSE CHILDREN Children that have not received any routine vaccine. Zero-dose children are defined here as those who lack the first dose of diphtheria-tetanus-pertussis containing vaccine (DTP1).

Foreword

Since its inception in 2000, Gavi embarked on a rewarding journey vaccinating over 1 billion children worldwide and saving 17 million lives. This extraordinary accomplishment stands as a testament to the incredible power of collaboration and forward-thinking in our mission to create a healthier future for all. Our progress would not have been possible without the unwavering support of our partners who share our vision of ensuring that every child receives the life-saving vaccinations.

At the heart of Gavi's mission lies innovation – the driving force behind our ability to adapt and address challenges preventing children from accessing vital vaccinations. Among these challenges, the most critical has been reaching the "zero-dose children" – those who have never received even a single dose of vaccine. Solving this issue requires an innovative approach that goes beyond conventional methods.

With diverse business and technology firms, we have been co-creating solutions for these challenges. One exemplary endeavor involves the groundbreaking work of Toyota Tsusho, which rose to the occasion by developing a customized Land Cruiser for the safe and efficient transportation of vaccines. Alongside other solution providers like B-Medical and Parsyl, we meticulously tested and monitored the usage of this WHO-prequalified vehicle over a span of 12 months. Our special appreciation goes to the respective Ministry of Health staff and our country programmes delivery teams who were willing to go the extra mile.

The insights gleaned from this introduction proved invaluable, underscoring that the real value of technology lies not solely in its capabilities, but in its capacity to be co-created and embraced by end-users. Our experiences across various countries revealed distinctive use cases, highlighting the necessity for adaptable and tailor-made solutions that cater to the unique needs of each region.

With this report, we happily share the outcomes of our collective efforts, providing decision-makers with essential data points and invaluable insights to guide the introduction of this inventive solution. Our aim is not to advocate for costly, high-tech solutions, but rather to champion the implementation of practical and customized solutions that genuinely impact the lives of vulnerable children.

As we move ahead, Gavi remains firmly committed to serving as a catalyst in this transformative process, fostering partnerships and nurturing innovation that will continue to shape the landscape of global immunization efforts. Together, we can build a world where no child is left behind, and every child can embrace a healthier, more radiant tomorrow.

Marie-Ange Saraka-Yao

Chief Resource Mobilisation
and Growth Officer

Executive Summary

This report presents an evaluation of the Vaccine Land Cruiser's performance in Niger, Burkina Faso, Senegal, and South Sudan, focusing on its ability to enhance access, efficiency, and safety in vaccine distribution. The Vaccine Land Cruiser, based on the robust Toyota Land Cruiser 78 series, integrates a custom-designed refrigerator from B Medical Systems, ensuring that vaccines are maintained at an optimal temperature of 2°C – 8°C during transportation, even in harsh climatic conditions and challenging terrain.

The report confirms that the Vaccine Land Cruiser **reached more locations** than the conventional methods used for vaccine transportation, **delivered more vaccines**, **accessed hard-to-reach areas** and thereby contributed to reducing the number of zero-dose children specifically in Burkina Faso.

An evaluation of cost-efficiency demonstrated the Vaccine Land Cruiser's significant potential for **reducing the overall cost of vaccine distribution**. A significant reduction in cost (up to 63%) per vaccine dose transported was observed across Niger, Senegal, and Burkina Faso, which may contribute to the sustainability of immunization programs in these countries.

The implementation process offered valuable lessons for optimizing the Vaccine Land Cruiser's performance and vaccine distribution. Key takeaways include the importance of pre-conditioning the refrigerator, pre-packaging vaccines, and strategic route planning to accommodate the refrigerator's temperature recovery time.

The adoption of a **push model**, where vaccines are delivered to clinics upon request instead of health workers having to collect them from district warehouses, freed up significant time for health workers at health clinics. Moreover, the tailored and immediate supply of vaccines in response to dynamic demand projections, facilitated by the Land Cruiser, allowed for more frequent outings with smaller volumes, improving distribution efficiency.

Moreover, the Vaccine Land Cruiser transcends its role as a mere cost-effective tool as it has the **potential to transform the immunization system design**. With real-time GPS tracking, logistics management is vastly improved, leading to a reduction in stockouts and ensuring a continuous supply of vaccines. Additionally, the vehicle offers the possibility of collecting used vials, syringes, and personal protective equipment through **reverse logistics**, promoting environmental sustainability and responsible disposal practices.

To ensure continuous improvement and knowledge sharing, it is recommended to establish a Community of Practice (CoP) among participating countries. This platform would enable users to generate and share ideas, knowledge, and best practices.

In conclusion, the Vaccine Land Cruiser presents an **efficient, cost-effective, and reliable solution for vaccine distribution** in regions facing challenging terrains and harsh climates. The report strongly recommends its widespread application and continuous enhancements to maximize its benefits and to optimize the immunization system design.

Dioundiou District, Dosso Region,Niger 2023.
Author: Hassane

Introduction

On March 21, 2021, the World Health Organisation (WHO) issued the first Performance, Quality and Safety (PQS) prequalification to a refrigerator vehicle which was jointly developed by Toyota Tsusho Corporation ("Toyota Tsusho") in collaboration with Toyota Motor Corporation ("Toyota"), and B Medical Systems S.à r.l. ("B Medical Systems"). Under the product code of E002/001, the vehicle met all the guidelines, specifications and protocols set by WHO for manufacturing vehicles that will be used to transport vaccines and pharmaceuticals at temperatures between 2°C and 8°C.

The vehicle is a **Toyota Land Cruiser 78 series** which has been fitted with a **396 liters net storage capacity** refrigerator in its back cabin. According to Toyota, the vehicle is designed for rough terrain and narrow roads which makes it fit to reach locations that are usually inaccessible with other vehicle types. The refrigerator has the capacity to store vaccines between 2°C to 8°C and **run on batteries for up to 16 hours** when disconnected from the main electricity supply after 6-8 hours of charging (See Annex 1 for specification).

In May 2021, Toyota Tsusho donated five Vaccine Land Cruisers to Gavi as part of an effort to support reaching the underimmunized and zero-dose children. In order to fully understand the impact the Vaccine Land Cruiser on the immunization program and supply chain, Gavi evaluated the introduction of the vehicles in five African countries for a period of 12 months. The vehicles were introduced by the Ministries of Health into the immunization supply chain program and evaluated against cost of transporting vaccines, access to locations and safe delivery of vaccines.

The evaluation report first describes the features of the Vaccine Land Cruiser. It then outlines the project's objectives and scope, followed by a comprehensive section on the methods and methodology used for data collection, analysis, tools, and evaluation processes across the five countries. The timeline section highlights the major activities that occurred throughout the project evaluation. The results section delves into the performance of the Vaccine Land Cruiser within three thematic areas: **access, cost efficiency, and the safe delivery of vaccines**. Each thematic area incorporates a set of indicators that have been meticulously utilized to monitor and evaluate the performance of the Vaccine Land Cruiser. The report concludes with a discussion on the potential of transformative change of the overall system design.

Dioundiou District, Dosso Region,Niger 2023.
Author: Hassane

Research Questions

In line with Gavi's Theory of Change, the evaluation of the Vaccine Land Cruiser sought out to provide answers to the following questions:[1]

Overarching question

How can the Vaccine Land Cruiser assist Gavi in achieving its 5.0 strategy (2021-2025) aimed at reaching under-immunized and zero-dose children in low-income countries facing logistical and accessibility challenges?

Sub-questions

- What are the **benefits of using the Toyota Vaccine Land Cruiser** compared to the conventional way of transporting vaccines?
- What is the best use of the Vaccine Land Cruiser to **maximize its impact on immunization**?

Thematic Areas

In this evaluation report, we delve into some of the challenges encountered in the global vaccine delivery efforts. Our primary focus is to assess the effectiveness of the Vaccine Land Cruiser initiative in overcoming these challenges. The evaluation revolves around three thematic areas: Access, Cost Efficiency, and Safe Delivery of Vaccines.

[1] See Annex 2 for Theory of Change of the introduction of the Vaccine Land Cruiser

Access

In the immunization programme, locations that cannot be easily accessible due to difficult terrain, bad or non-motorable roads are termed as hard-to-reach areas. These are locations that face supply chain barriers "due to geography by distance or terrain, transient or nomadic movement, healthcare provider discrimination, lack of healthcare provider recommendations, inadequate vaccination systems, war and conflict, home births or other home-bound mobility limitations, or legal restrictions"[2]. These hard-to-reach areas are usually home to zero dose children ie. children who have not received a single dose of diphtheria, tetanus and pertussis– containing vaccines. Gavi estimates that about 18 million[3] children in 2021 did not receive a single dose of vaccine, making them vulnerable to preventable diseases. By 2025, Gavi aims to reduce the number by 25% and by 2030 to reduce it by 50%[4].

In addressing the challenges accessing vaccines, this project focuses on solving problems related to vaccine transportation and making vaccines available in health facilities. The use of the Vaccine Land Cruiser to reach zero-dose children and hard-to-reach locations will be evaluated.

Cost Efficiency

Transportation cost of vaccines places a huge burden on immunization supply chain systems and health workers. Vaccine supply is usually fixed according to a supply frequency that minimizes cost rather than fulfilling on-demand needs. Health facilities with cold chain equipment for storing vaccines receive their supplies on a monthly basis. Health facilities without cold chain equipment often travel to district stores or nearby facilities to collect vaccines and return it after the day's immunization session. By substantially reducing the cost of transporting vaccines, immunization supply chain managers can reprogram available funds to increase supply, reduce time-spent on logistics by health workers and strengthen other health systems.

Safe Delivery of Vaccines

Vaccines are both time-sensitive and temperature-sensitive, requiring strict adherence to temperature guidelines to maintain their effectiveness. The distribution of vaccines poses one of the greatest risks to their quality, as stated by the WHO[5]. Freeze-sensitive vaccines are often transported with frozen or improperly conditioned ice packs, which can expose them to freezing temperatures. The primary cause for this issue is the widespread lack of compliance with proper ice pack conditioning. Research has demonstrated that vaccines frequently experience temperature fluctuations during transport. For instance, a 2019 study conducted across 21 districts in three Indian states found that 9%-35% of vaccines were exposed to freezing temperatures, while 0.8%-11.3% experienced heat exposure above 8°C during facility transportation to facility[6]. In a separate study from 2017, which followed the WHO Vaccine Temperature Monitoring Protocol in Cameroon, it was revealed that 83% of shipments containing Diphtheria-Tetanus and Pertussis vaccine vials were exposed to freezing temperatures[7].

The evaluation of the Vaccine Land Cruiser will monitor the temperature of vaccines during transportation to ensure that vaccines are safely delivered at the right temperature as recommended by WHO. In addition to this, damage of vaccine vials due to breakage will also be monitored.

[2] Ozawa, S., Yemeke, T. T., Evans, D. R., Pallas, S. E., Wallace, A. S., & Lee, B. Y. (2019). Defining hard-to-reach populations for vaccination. Vaccine, 37(37), 5525–5534. *https://doi.org/10.1016/j.vaccine.2019.06.081*
[3] *https://data.unicef.org/wp-content/uploads/2016/07/progress-challenges_wuenic2021.pdf*
[4] *https://www.gavi.org/vaccineswork/zero-dose-child-explained*
[5] World Health Organization. (2006). Temperature sensitivity of vaccines. World Health Organization. *https://apps.who.int/iris/handle/10665/69387*
[6] Das, M. K., Arora, N. K., Mathew, T., Vyas, B., Sindhu, M., & Yadav, A. (2019). Temperature integrity and exposure to freezing temperature during vaccine transfer under the universal immunization program in Three States of India. Indian journal of public health, 63(2), 139–142. *https://doi.org/10.4103/ijph.IJPH_123_18*
[7] Yauba, Saidu & Sobngwi, Joelle & Jude, Nkwain & Tracy, Biloa & Kobela, Marie & Charles, Nsangou & Hermelle, Ename & Marius, Vouking & Julius, Sama & Alain, Biloa & Baku, Adan & Marianne, Mbollo & Mike, Brison & Kamga, Delphine & Robinson, Mbu & Divine, Nzuobontane. (2017). Temperature Monitoring in the Vaccine Cold Chain in Cameroon. Journal of Vaccines & Vaccination. 09. 10.4172/2157-7560.1000384.

Project Scope

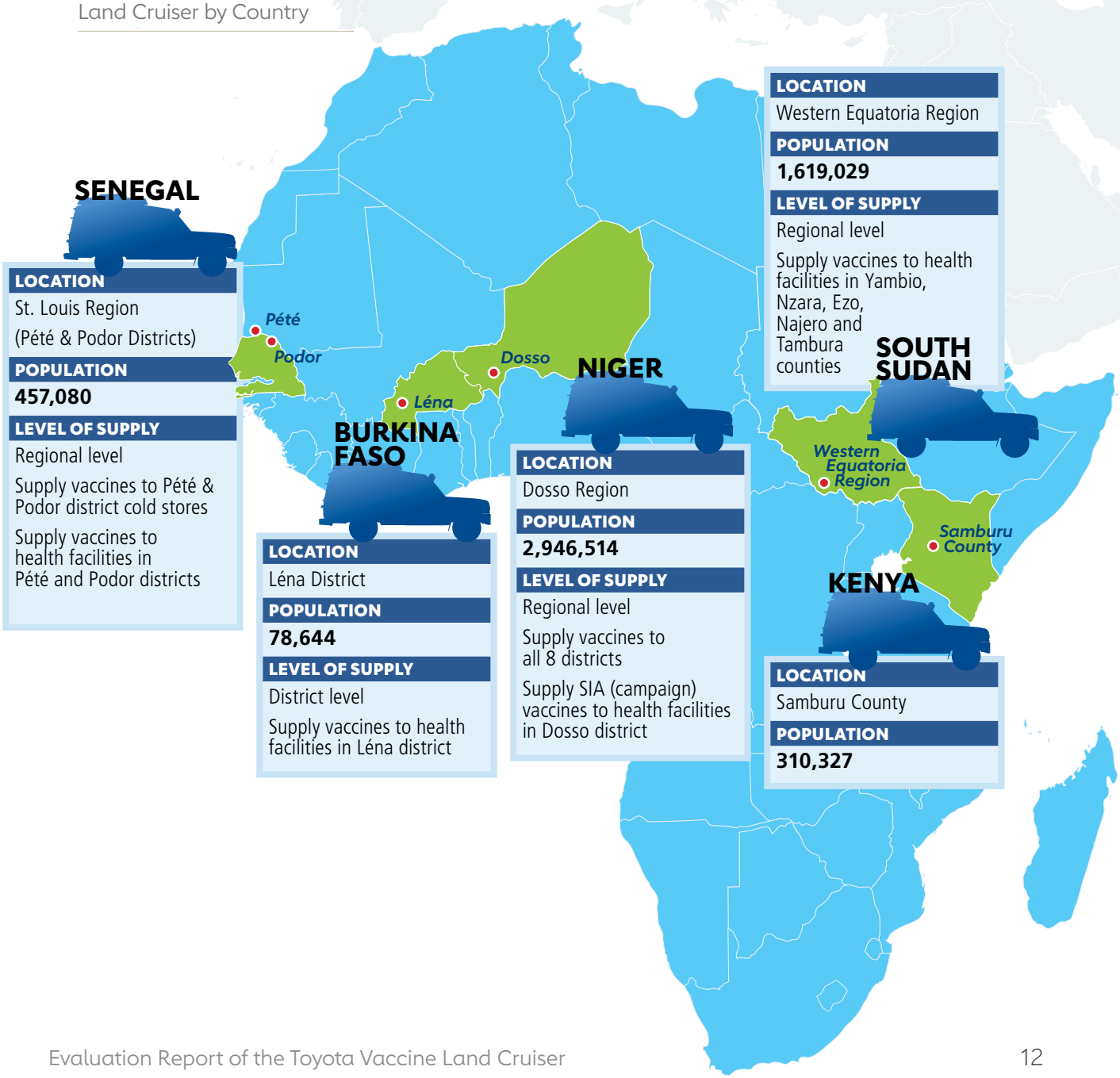
The priority use of the vehicle is to transport vaccines in the first place and possibly other public health related commodities that require cold chain.

Locations

In each of the five African countries where the Vaccine Land Cruisers were deployed, specific locations were selected for operation by the country's Ministries of Health and their major stakeholders. Ministries of Health were encouraged to deploy the vehicles to locations with high numbers of zero-dose children, missed communities or areas with urgent need of a vehicle for vaccine transportation.

The image below summarizes the locations selected by each country:

Deployment of the Vaccine Land Cruiser by Country



Stakeholders

Stakeholder engagement was a crucial aspect of this project. The stakeholder mapping process involved identifying relevant organizations and individuals across different sectors, such as donors, project teams, implementing partners, and advisors. Throughout the project, regular communication channels, such as meetings, workshops, and reports, were organised to keep stakeholders informed and engaged. This continuous dialogue allowed for valuable feedback and input from various perspectives, which contributed to the project's overall effectiveness.

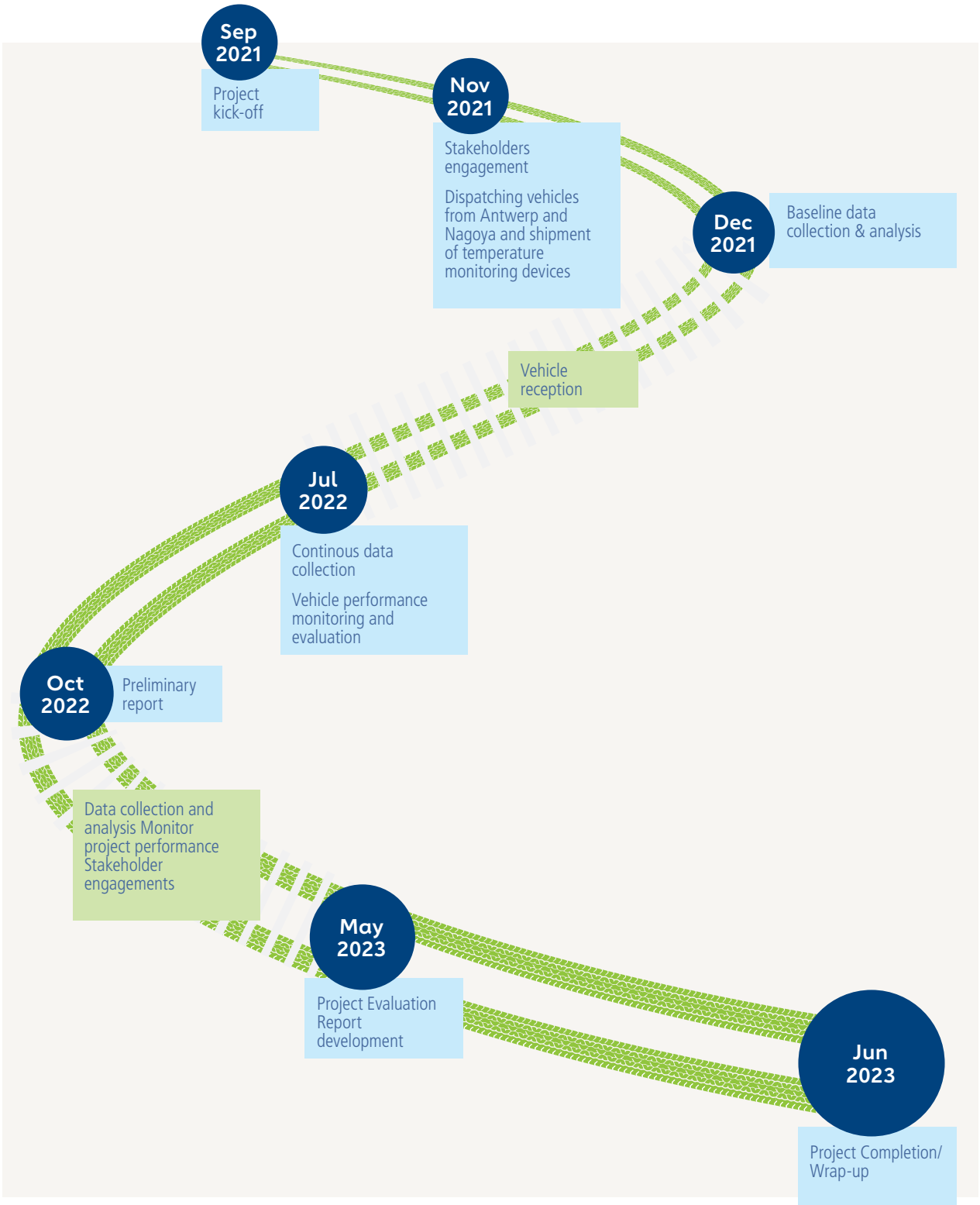
The image below describes the role of each stakeholder in the Vaccine Land Cruiser introduction:

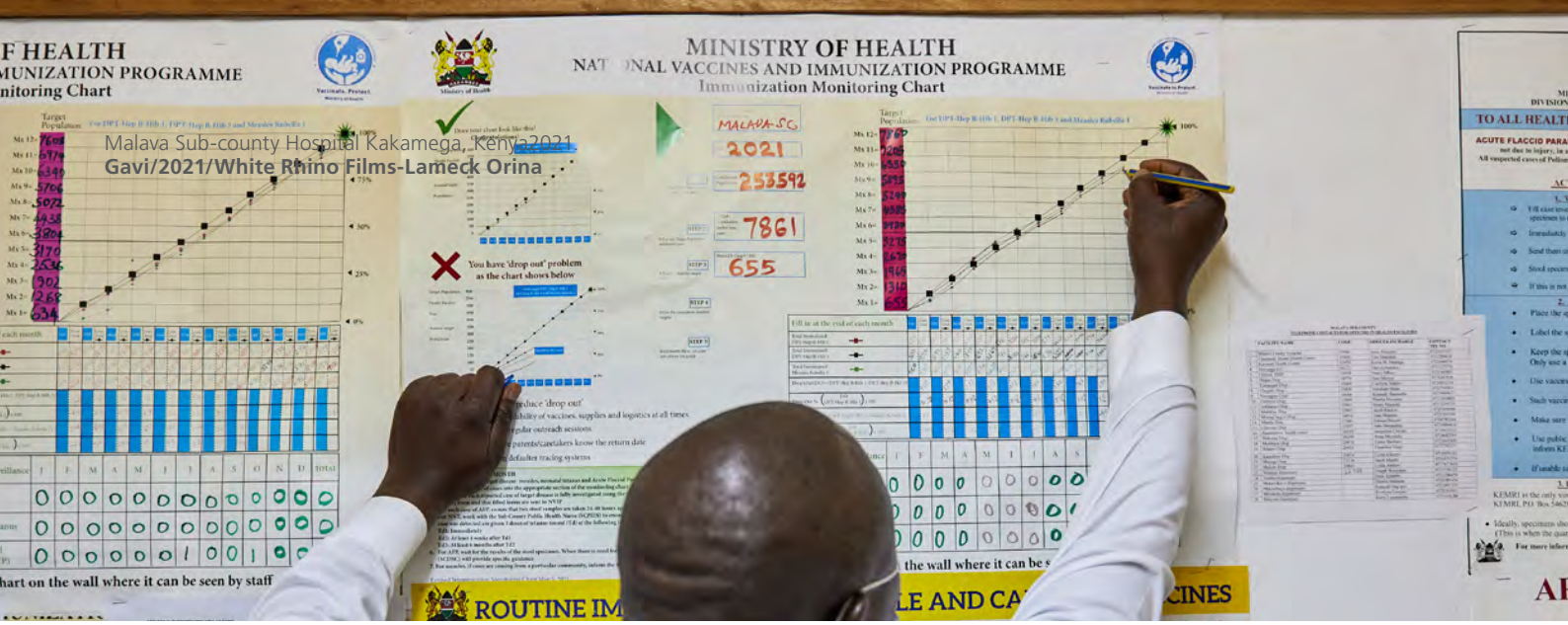
Stakeholders for the Evaluation of the Vaccine Land Cruiser Introduction

Project Duration

The evaluation of the Vaccine Land Cruiser introduction was initially planned for an 18-month period, commencing in September 2021. However, due to unforeseen delays in shipment, freight forwarding, and port clearance, the vehicles could not operate before June 2022. Consequently, the project timeline was extended to June 2023, resulting in a total duration of 22 months.

Timeline of the the Evaluation of the Vaccine Land Cruiser





Malava Sub-county Hospital Kakamega, Kenya 2021
Gavi/2021/White Rhino Films-Lameck Orina

Methods and Methodology

The Methods and Methodology section outlines the approaches, techniques, and procedures employed to evaluate the Toyota Vaccine Land Cruiser's impact on the immunization program and its supply chain in five African countries – Niger, Senegal, Burkina Faso, South Sudan, and Kenya. The evaluation's framework, including data collection and analysis methods, is structured within the study design subsection to provide a comprehensive and cohesive presentation of the evaluation process. This section also highlights the efforts made to minimize the burden of data collection on the Ministries of Health and to ensure that the evaluation is based on reliable, accurate, and timely information.

The following subsections within the Methods and Methodology section provide details on various aspects of the evaluation process:

1. **Study Design:** Describes the mixed-methods approach used in the evaluation, combining quantitative and qualitative data collection and analysis. The study design includes baseline data collection, Vaccine Land Cruiser monitoring and evaluation, data analysis, and the development of guidelines and recommendations.

2. **Data Collection:** Explains the different methods used for collecting data during the evaluation, such as routine immunization supply chain reporting, automated data collection, and interviews and focus group discussions.

3. **Data Analysis:** Provides an overview of the techniques used to analyze both quantitative and qualitative data, such as descriptive and inferential statistical analyses and thematic analysis.

4. **Development of Guidelines and Recommendations:** Describes the process of using the evaluation findings to create guidelines and recommendations for future usage and development of the Vaccine Land Cruiser and potential improvements to the immunization supply chain in the selected locations.

Study design

For Niger, Senegal and Burkina Faso, the project design was a multi-country pre-post evaluation whereas for South Sudan, the study design was cross-sectional.

The study design consists of the following components:

1. **Baseline data collection:** Before the introduction of the Vaccine Land Cruiser, baseline data was collected to provide a reference point for comparing the performance of the vehicle against conventional methods of vaccine transportation. This data included information on accessibility, supply-chain challenges, transportation costs, and vaccine delivery safety in the selected locations.

2. **In Niger, Senegal, and Burkina Faso**, the **pre-post study** collected data on vaccine distribution from the conventional vehicle 12 months prior to the intervention as baseline data and compared it against the data produced by the Vaccine Land Cruiser.

3. **In South Sudan**, due to security challenges and limited data availability, the evaluation of the Vaccine Land Cruiser was a **prospective cross-sectional study**. Both the Vaccine Land Cruiser and the conventional vehicle used for vaccine transportation were studied together, allowing for a direct comparison of their performance in geographically similar areas.

4. **Vaccine Land Cruiser monitoring and evaluation:** Data was collected throughout the evaluation period to monitor and evaluate the performance of the Vaccine Land Cruiser against a set of predefined indicators centered around three thematic areas – access, cost efficiency, and safe delivery of vaccines. Data collection methods included:

    a. **Immunization supply chain reporting:** Data generated by the immunization supply chain reporting activities in the selected locations was used to assess the performance of the Vaccine Land Cruiser.

    b. **Automated data collection:** Data generated from the Vaccine Land Cruiser, such as temperature monitoring and GPS tracking, was automated and transmitted in real-time via internet and satellite connections.

    c. **Interviews and focus group discussions:** Qualitative data was collected through interviews with health workers, supply chain managers, and other stakeholders to gain insights into the benefits and challenges of using the Vaccine Land Cruiser, as well as recommendations for future usage and development.

5. Data analysis: Both quantitative and qualitative data were analyzed to assess the performance of the Vaccine Land Cruiser in the selected locations. Descriptive and inferential statistical analyses were conducted to examine the relationships between the Vaccine Land Cruiser and the predefined indicators. Qualitative data analysis techniques, such as thematic analysis, were used to identify patterns and trends in the interview and focus group data.

6. Development of guidelines and recommendations: Based on the findings of the evaluation, guidelines and recommendations were developed to inform future usage and development of the Vaccine Land Cruiser, as well as potential improvements to the immunization supply chain in the selected locations.

The study design aimed to minimize the burden of data collection on the Ministries of Health and ensure that the evaluation was based on reliable, accurate, and timely information. By combining quantitative and qualitative data collection methods, as well as pre-implementation and prospective study designs, the study design provided a comprehensive assessment of the impact of the Vaccine Land Cruiser on the immunization program and supply chain in the selected countries.

Data collection, tools and procedure

BASELINE DATA

Baseline data was collected by a secondary data collection method. This involved collecting data from previous year's Stock Management Tools (SMT), District Vaccination Data Management Tool (DVDMT), District Health Information System (DHIS) and any other tool used for reporting vaccine storage, distribution, wastage etc.

The baseline data was divided into three categories. Each category collects data that will provide information and set a baseline for evaluating the Vaccine Land Cruiser. The location information category collects data on the location which the Vaccine Land Cruiser will be used to deliver vaccines. The vaccine delivery category collects data on the routine and supplemental immunization vaccines that will be transported by the Vaccine Land Cruiser. And finally cost category collects baseline data on costs incurred transporting vaccines with the conventional vehicle.

Location information

- Names and location of storage points and health facilities
- GPS coordinates
- Hard-to-reach facilities

Vaccine delivery

- Vaccine types used for routine immunization and other supplemental immunization programmes
- Vaccine storage volume
- Number of doses distributed/transported for the previous year
- Frequency of vaccine supply
- Mode of vaccine distribution (push, pull, mixed)
- Target population of the locations in which the Vaccine Land Cruiser will be used
- Number of DTP-1 (PENTA-1) immunized for previous years by month

Cost of transporting vaccines with the conventional vehicle

- Conventional vehicle used for vaccine deliveries for each administrative level (type, storage size)
- Fuel cost per liter
- Distance to locations from supplying stores
- Vehicle fuel consumption per kilometer
- Number of staff involved in deliveries & per diem rate
- Maintenance cost (servicing & repairs)

MONITORING DATA

Automated data and immunization supply chain reports were used to measure the performance, utilization, and impact of the Vaccine Land Cruiser. Automated data was generated directly from the vehicle with minimal user initiation, and it included:

1. **Global Positioning System (GPS):** Installed by the vehicle manufacturer, this system automatically transmitted location data every 15 minutes to the HumanNav Vehicle Tracking web application.

2. **Continuous Temperature Monitoring Devices:** Three Parsyl Trek Pro devices were placed in the Vaccine Land Cruisers to record internal and external temperatures, as well as ambient temperature within the vehicle. These devices were pre-programmed to record temperature and humidity every 10 minutes and wirelessly transmitted data to the Parsyl web application.

3. **Supply Chain Reporting Activities:** Data from regular storage and distribution activities in the countries was collected, and Ministries of Health Cold Chain Officers were asked to share reports for every vaccine distribution carried out with the Vaccine Land Cruiser and conventional vehicle.

Data for Monitoring the Vaccine Land Cruiser

GPS data

- Date
- Asset
- Country
- Location (GPS coordinates)
- City
- Alert State
- Engine Activity Duration
- Mileage
- Engine
- Engine Idle
- Ignition
- External Voltage
- Speed
- Overspeeding
- Overspeeding Duration
- Events
- Street
- Points of Interest

Continuous temperature monitoring device data

- Date
- Time
- Trek ID
- Temperature (C)
- Humidity (Rh)

Supply chain reporting activities data

- Number and types of vaccine doses distributed
- Costs of vaccine transportation (fuel, per diems, maintenance and repairs, etc)
- Wastage (closed vial, temperature damage, etc)
- Zero dose (target population and DTP-1 immunized)

Regular meetings were held with implementing partners to obtain qualitative data, including information on overall experiences, challenges faced during vaccine distribution, and recommendations. These meetings also served as opportunities to review and verify data shared during or after vaccine distributions.

Data analysis

To ensure a comprehensive evaluation of the Vaccine Land Cruiser project, a systematic data collection and reporting process was employed. This process involved the use of data collection protocols containing templates for sharing baseline data, which were disseminated to the Ministries of Health (MOH) and their respective focal points. The protocols were completed and returned via email by Niger and Burkina Faso. In Senegal, the project manager and project evaluator conducted interviews to collect baseline data and obtained historical data directly from focal persons designated by the MOH. Baseline data were gathered before the operationalization of the Vaccine Land Cruisers.

The data analysis framework involved collating data from all methods in spreadsheets, while data from the Toyota GPS client and Parsyl temperature monitoring devices were exported in KML and CSV formats. All collected data were categorized into three main aspects: access, efficiency, and safe delivery of vaccines. Each of these categories contains specific indicators used for evaluating the performance of the Vaccine Land Cruiser project.

Indicators Used for Evaluating the Vaccine Land Cruiser

Access

- Number of doses delivered
- Number of locations reached (baseline vs. Vaccine Land Cruiser)
- Number of zero-dose children reached (2023, 2022, 2021, 2020)

Efficiency

- Vaccine transport cost per dose (baseline vs. Vaccine Land Cruiser)
- Proportion of Vaccine Land Cruiser operational cost for transporting vaccines

Safe Delivery of Vaccines

- Temperature of vaccines in transportation
- Average temperature of vaccines in transportation
- Number of vaccine vials/doses damaged from temperature excursion and breakage in transportation (baseline vs. Vaccine Land Cruiser)

The data analysis framework allowed for a detailed and technical assessment of the Vaccine Land Cruiser project, enabling the evaluation team to generate insights into the project's performance across the access, efficiency, and safety dimensions.

A comprehensive methodology was developed to combine data from the driver logbook with GPS and temperature data to obtain accurate information. The following steps outline the process:

1. Data was gathered from three primary sources: the driver logbook, GPS tracking devices, and temperature sensors. The driver logbook contained information about the start and end times of each trip, while the GPS devices recorded the vehicle's location (latitude and longitude) at regular intervals. The temperature sensors monitored the internal, ambient and external temperatures of the vaccine storage area within and outside the vehicle.

2. Before merging the data, several preprocessing steps were performed to ensure consistency and accuracy. These steps included:

    a. Converting timestamps to a standardized format (datetime objects)

    b. Removing duplicate records based on rounded timestamps

    c. Rounding the timestamp to the nearest 10 minutes to facilitate data merging

3. Merging Temperature Data with Driver Logbook Data: Temperature records were filtered based on the start and end times logged in the driver log book, ensuring that only temperature data corresponding to each trip was retained. A new dataframe containing only the relevant temperature data was created.

4. Merging GPS Data: The GPS data was merged with the filtered temperature data by aligning the rounded timestamps. This process created a new dataframe with combined information from the driver logbook, GPS tracking devices, and temperature sensors.

5. Calculating Distance and Duration: The distance traveled and the duration of each trip were calculated using the GPS data. The distance was computed using an appropriate method such as the Haversine formula or external APIs like OpenStreetMap's OSRM, while the duration was calculated by taking the difference between consecutive timestamps within the same day from the vehicle's logbooks.

6. Data Analysis: With the merged data, various analyses were performed to gain insights into the transportation process, such as calculating the average temperature during transportation, determining the total duration of transportation, and assessing the impact of transportation on vaccine quality.

By following this methodology, data from the driver logbook, GPS devices, and temperature sensors was successfully combined to obtain accurate information on the transportation of vaccines. This comprehensive approach allowed for drawing meaningful conclusions about the performance of the transportation system and its impact on vaccine quality.

Constraints

During the implementation and evaluation of the Vaccine Land Cruiser project, several constraints were encountered which impacted the study design and data collection processes. Acknowledging these constraints is essential for providing a better understanding of the project's context and limitations. The following constraints were identified:

1. Security Challenges in South Sudan: The security situation in South Sudan posed significant challenges to the project's implementation and data collection process. The limited data availability may have affected the comprehensiveness and accuracy of the evaluation in these locations.

2. Inconsistencies in Reporting: The reliance on supply chain reporting activities from various Ministries of Health and Cold Chain Officers may have resulted in inconsistencies in the data collected. Different levels of record-keeping quality and variations in reporting formats may have impacted the comparability and accuracy of the data used for the evaluation.

3. Limited Direct Observation: Direct observation of vaccine distribution processes was not possible in all locations. This limitation restricted the project team's ability to collect first-hand qualitative data on the Vaccine Land Cruiser's performance and user experiences. As a result, the evaluation may have relied more heavily on secondary data sources and stakeholder feedback, which could be subject to biases or inaccuracies.

To mitigate the impact of these constraints on the project's outcomes, the project team employed various strategies such as triangulating data sources, engaging in regular meetings with implementing partners, and adjusting the study design when necessary. Despite these limitations, the project provided valuable insights into the performance and potential of the Vaccine Land Cruiser as a cold chain solution in the targeted African countries.

Exclusions

In order to maintain the validity and reliability of the project's findings, certain exclusion criteria were established to guide the data collection and analysis process. These criteria helped to ensure that the data used in the evaluation was representative, relevant, and accurate. The following exclusion criteria were applied during the study:

1. Locations Outside Vaccine Land Cruiser Deliveries: Locations which do not receive deliveries with the Vaccine Land Cruisers were excluded from the evaluation.

2. Incomplete or Inaccurate Data: Data sets with missing or inconsistent information were excluded from the analysis. This helped to maintain the integrity of the project's findings and ensure that the conclusions drawn were based on accurate and reliable data.

3. Irrelevant Data: Any data that was not directly related to the project's objectives or did not pertain to the specific geographical locations and vaccine distribution processes under investigation was excluded from the evaluation. This helped to maintain focus on the project's primary goals and ensure that the analysis was relevant and targeted.

4. Data from Non-Representative Time Periods: To maintain a consistent and representative time frame for the evaluation, data from periods falling outside the specified project duration or time periods that did not accurately represent typical vaccine distribution processes were excluded from the analysis. This exclusion includes instances when temperature data was recorded by the Parsyl devices during periods when vaccines were not being transported, but the devices remained active. By focusing on relevant and representative data, the analysis and subsequent findings were more accurately reflective of the true vaccine distribution process and the performance of the Vaccine Land Cruiser.

5. Exclusion of Per Diem Costs in Overall Cost per Dose Calculation: In the evaluation of the overall cost per dose for vaccine distribution, the cost of per diems for staff involved in the delivery process was excluded. This exclusion was applied as the per diem rates remained constant and unchanged for both the baseline (conventional vehicle) and the Vaccine Land Cruiser scenarios. By excluding these constant costs, the analysis focused on the differences in other cost components, providing a more accurate representation of the impact of the Vaccine Land Cruiser on vaccine distribution expenses.

By applying these exclusion criteria, the research team was able to maintain the rigor and quality of the project's evaluation, ensuring that the findings were both meaningful and generalizable to the broader context of vaccine distribution and cold chain management.

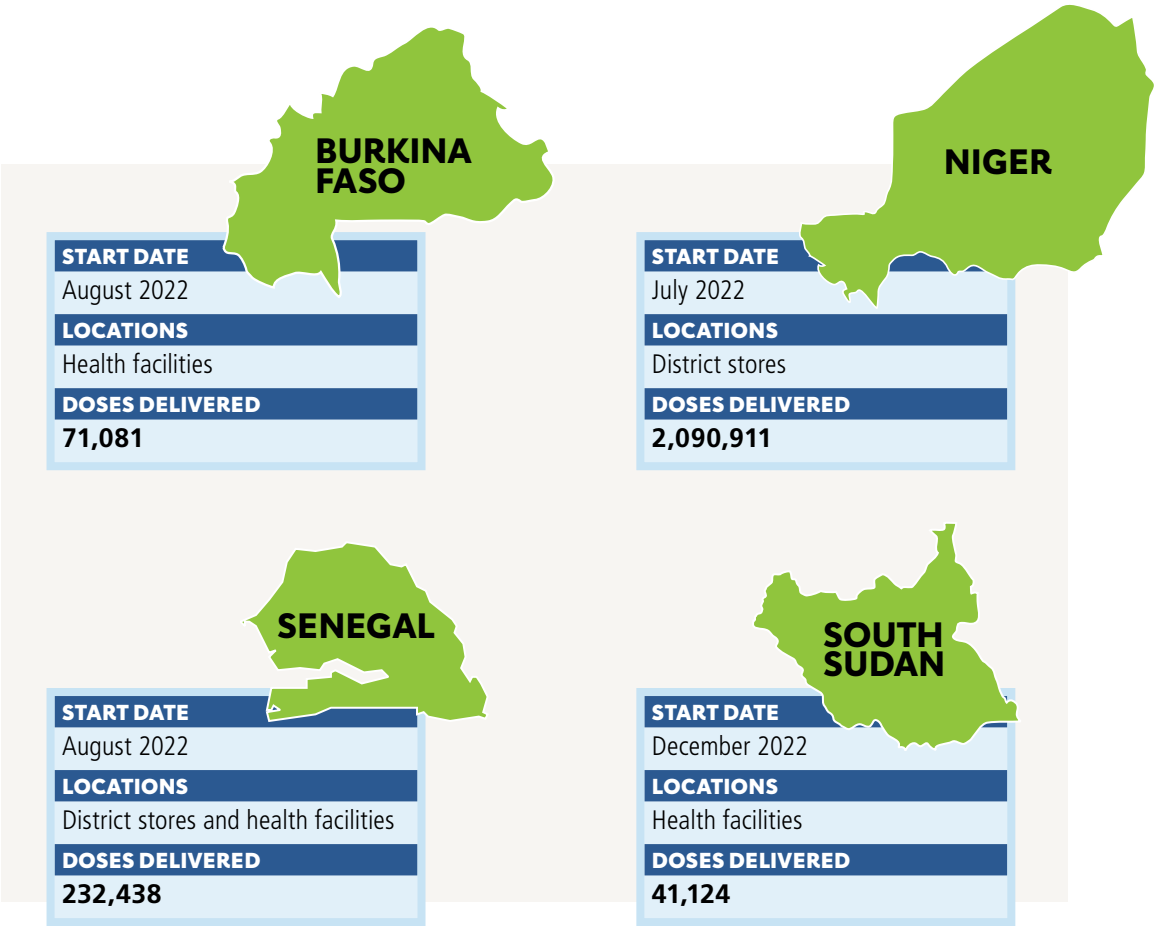
Gavi by Isaac Griberg, Niamey, Niger, Dec 2022

Results

This section explores the impact of the Vaccine Land Cruiser project across Niger, Burkina Faso, Senegal, and South Sudan. The evaluation examines the impact of the Vaccine Land Cruiser on immunization supply chain access, efficiency, and safety, using quantitative and qualitative data. Key performance indicators include the number of doses delivered, locations reached, zero-dose children served, and cost efficiency comparisons between the Vaccine Land Cruiser and conventional transportation methods. Finally, safe vaccine delivery aspects such as temperature control and damage rates during transport are analyzed.

Throughout the evaluation period for the Vaccine Land Cruiser initiative, a total of 477 vaccine deliveries were successfully executed across four different countries: Niger, Senegal, Burkina Faso, and South Sudan. These deliveries encompassed ten distribution rounds, leading to a total of 2,435,554 doses of vaccines distributed.

Breakdown of Vaccine Doses Distributed by Country



The following sections provide a detailed analysis of the results for each category, which offer valuable insights into the overall effectiveness of the Vaccine Land Cruiser project in improving vaccine distribution and accessibility in hard-to-reach areas.

Mr. Amadou Maitchibi,
Dosso Regional EPI Driver, Niger.

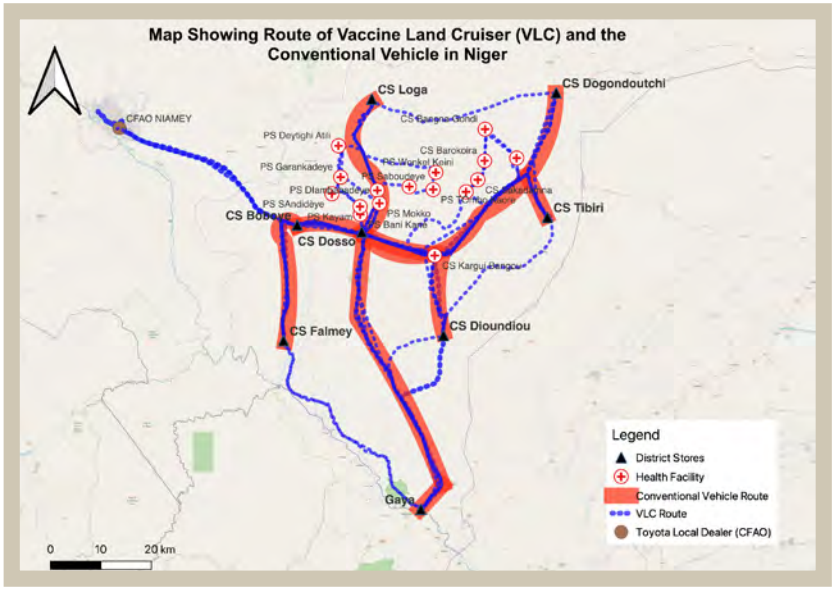
Access

The Vaccine Land Cruiser was successful in accessing all targeted locations for vaccine distribution within the countries of Niger, Senegal, and Burkina Faso throughout the evaluation period. The vehicle served as the primary delivery method for all eight district stores within the Dosso region in Niger, for 68 health facilities across the Pété and Podor districts within the Saint Louis region of Senegal, for 16 health facilities in the Léna district of Burkina Faso, and for 13 distinct locations, including counties and health facilities, within the Western Equatorial state of South Sudan.

Interestingly, the Vaccine Land Cruiser was utilized as a direct replacement for the conventional vehicles previously used for transporting vaccines across all four countries. Comparative data reveals that the Land Cruiser was able to access an increased number of locations. In Niger for example, while conventional vehicles were previously limited to delivering vaccines to district stores, the Vaccine Land Cruiser significantly expanded this distribution capacity. It was employed to transport critical Covid-19 vaccines and measles campaign vaccines directly to 16 health facilities within the Dosso region of Niger during the months of September and December in 2022. The map provided below offers a visual representation of this increased reach, illustrating the **locations accessed by the conventional vehicle (depicted in red lines) compared to those reached by the Vaccine Land Cruiser (indicated by blue dotted lines)**.

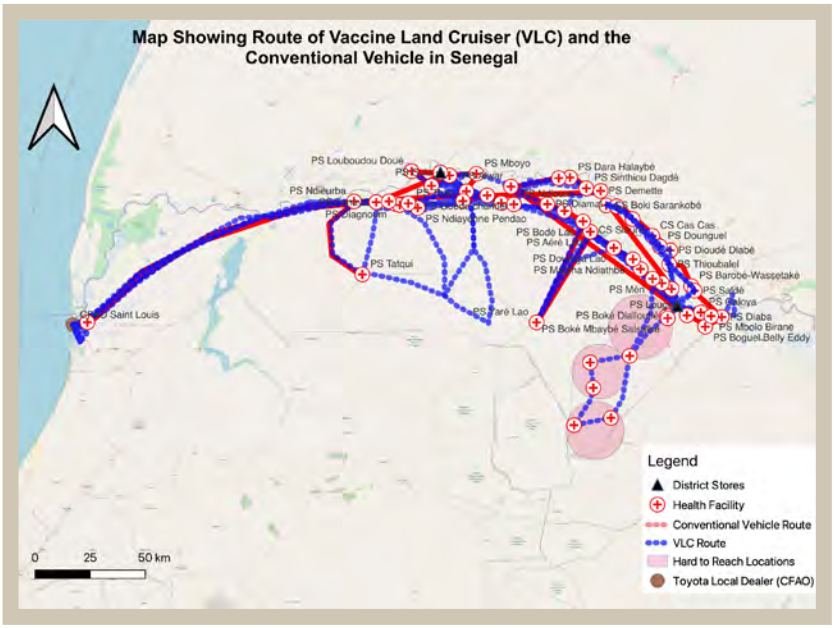
> **"The major challenge is the road condition, but with this all-road vehicle I can go anywhere with no major problems."**
>
> **Mr. Amadou Maitchibi**, EPI Driver, Dosso Region, Niger

Niger: Map of Dosso Region Showing the Locations Reached by the Vaccine Land Cruiser



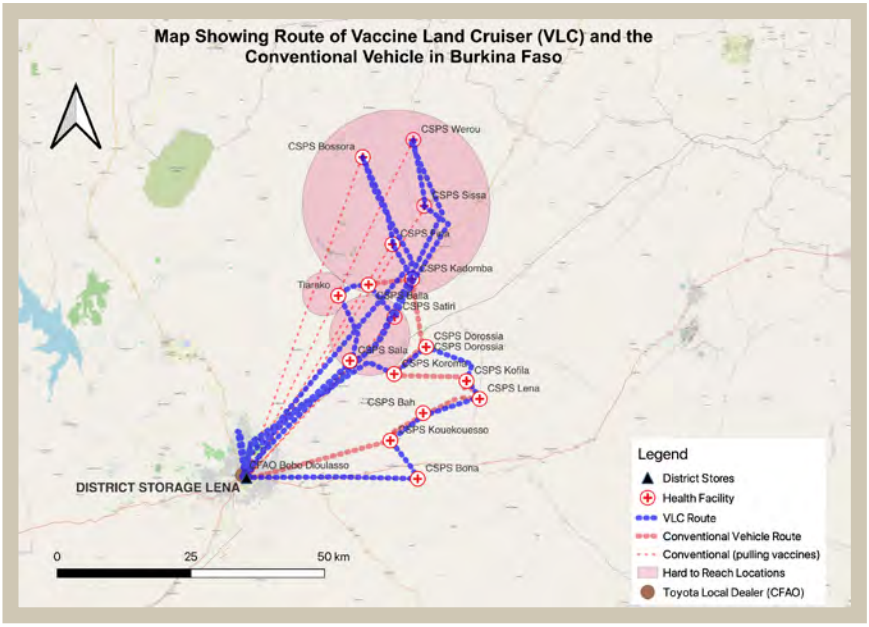
In the Pété district of Senegal, specifically along the Diéry axis, the Vaccine Land Cruiser was able to reach two of the six health facilities, previously unattainable by the conventional vehicle.

Senegal: Map of Pété & Podor Districts Showing the Locations Reached by the Vaccine Land Cruiser



In Burkina Faso's Léna district, prior to the deployment of the Vaccine Land Cruiser, health facilities relied on motorbikes to retrieve vaccines from the district store monthly, adhering to a 'pull' system. Nine health facilities, located along the axis of Bossora and Werou – an area informally referred to by logistics staff as *l'axe du mal* or 'axis of evil' – were effectively disconnected from the immunization supply chain due to impassable roads, particularly during the rainy season. However, since the implementation of the Vaccine Land Cruiser in August 2022, these facilities have been receiving consistent monthly vaccine supplies.

Burkina Faso: Map of Léna District Showing the Locations Reached by the Vaccine Land Cruiser

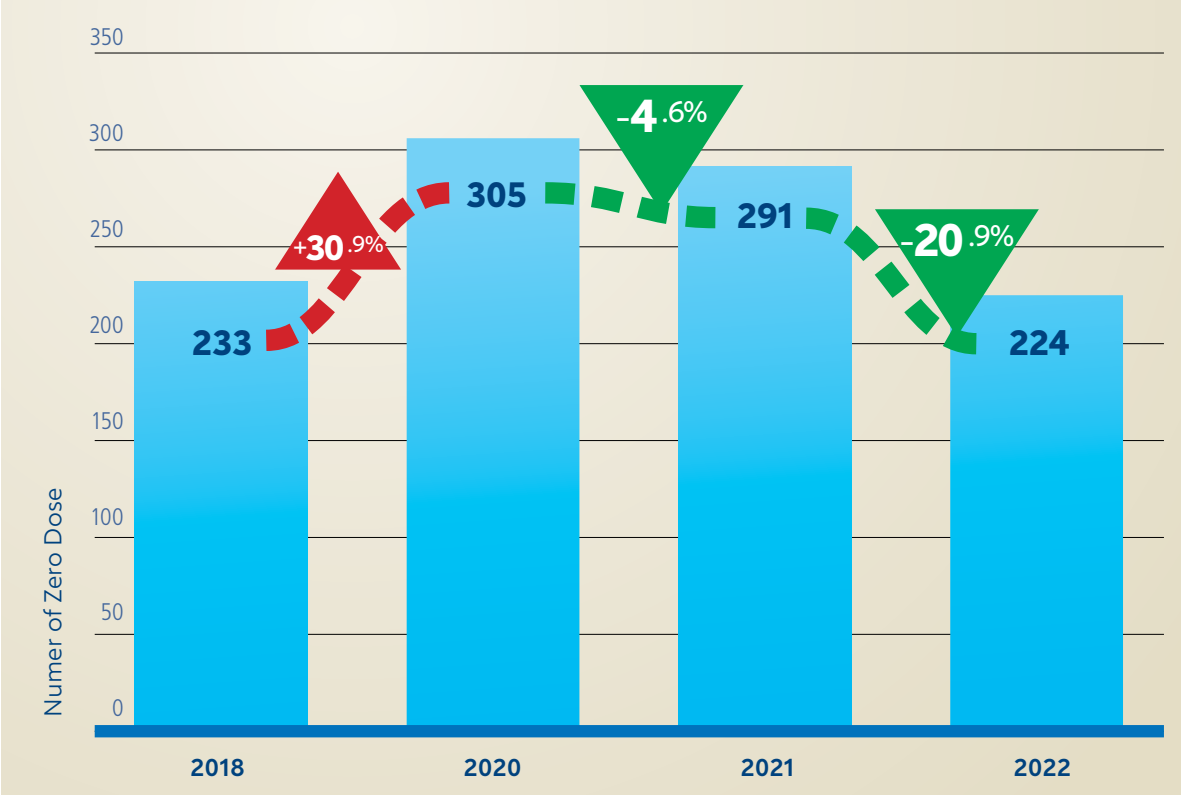


The data collected throughout this period clearly underlines the enhanced accessibility and versatility provided by the Vaccine Land Cruiser in comparison to traditional vaccine transport methods.

> **"The biggest challenge (...) is the hard-to-reach location, particularly during the rainy season. This is the season with major challenges, when doing vaccination campaigns."**
>
> **Mr. Gué Gautier**, Head Nurse at Werou Health Post, Léna District, Burkina Faso

Data pertaining to zero dose vaccinations was exclusively collected from Léna district of Burkina Faso for the years 2018, 2020, 2021, and 2022, with the 2022 data extending only up until November. The reason for the exclusive focus on Burkina Faso for zero dose data analysis was due to the availability of consistent and reliable tracking of zero-dose children in this country. It is worth noting that the Vaccine Land Cruiser came into operation in July 2022 and began vaccine distributions in August of that same year. During the challenging period of the COVID-19 pandemic in 2020, the number of zero-dose children increased by 30%. It followed a slight decrease in 2021 and a steep decline of 23% in 2022. This is thanks to the concerted efforts by all stakeholders, including the introduction of the Vaccine Land Cruiser to ensure consistent vaccine supply to healthcare facilities, have significantly contributed to the decline in the count of zero-dose children in the Léna district of Burkina Faso.

Chart showing Number of Zero Dose Children in Léna District (2018, 2020, 2021, 2022)



Dr. Goumbane Nanimpo Birèmina,
Head Doctor of Léna District, Burkina Faso.

Efficiency

The efficiency of the Vaccine Land Cruiser was evaluated by comparing the costs associated with vaccine delivery per dose using the Vaccine Land Cruiser versus the conventional transportation methods employed in Niger, Senegal, and Burkina Faso. In the case of South Sudan, a similar cost comparison was not undertaken due to the static nature of the transportation costs, which remained fixed per delivery location, irrespective of the vehicle used, as dictated by the implementing partner.

Vaccine Transport Cost per Dose

The transport cost per dose is a measure of the total operational expenditure on vaccine delivery divided by the quantity of doses transported. The costs incorporated into this calculation for both the Vaccine Land Cruiser and conventional vehicles include fuel and maintenance, or the lump sum provided to healthcare workers for vaccine pickup. However, per diem costs have been excluded from this comparison as they remain consistent for both modes of transport.

It should be noted that the baseline cost per dose is not constant across all countries, as it depends on the delivery methods utilized in the 12 months leading up to the introduction of the Vaccine Land Cruiser. To ensure a fair comparison, the baseline costs included in this analysis consider the cost of delivering vaccines to the identical locations served by the Vaccine Land Cruiser.

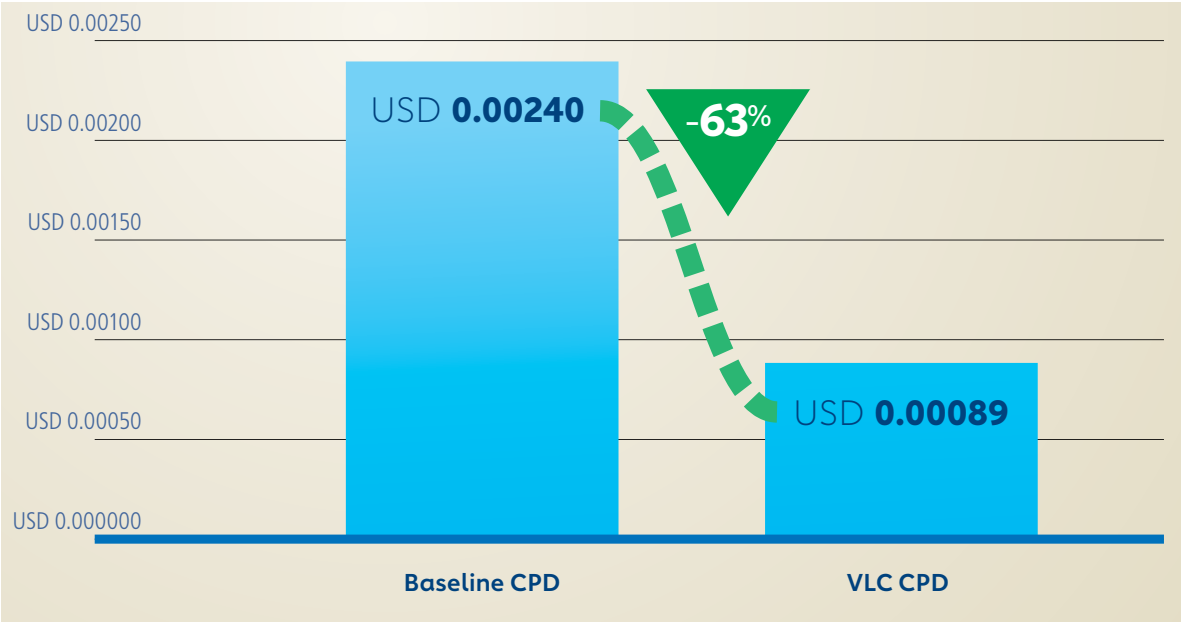
NIGER

In the Dosso region of Niger, prior to the deployment of the Vaccine Land Cruiser, the conventional means of vaccine transportation was a 4x4 Toyota Hilux, outfitted with a locally constructed refrigerator on the truck bed, boasting a storage capacity of 3,900 liters. However, this vehicle lacked the capacity to store dry commodities, necessitating the use of an additional truck for such deliveries.

Conventional Vehicle for Transporting Vaccines in Dosso Region Niger

The average baseline cost of transporting vaccines per dose to the eight districts within the Dosso region amounted to USD 0.00240. Conversely, the Vaccine Land Cruiser demonstrated a significant cost advantage, with an average transportation cost per dose of just USD 0.00089. This equates to a substantial 63.07% reduction in the cost of vaccine distribution.

Niger: Average Cost per Dose of Transporting Vaccines (Dosso Region)



Despite the higher volume of vaccine doses transported by the conventional vehicles in the comparable period, the associated baseline costs are significantly higher than those incurred by the Vaccine Land Cruiser. The baseline cost calculation in Niger accounts solely for fuel consumption, estimated at 20 liters per 100 kilometers for a round trip to each district store from the regional store using two separate trucks – one for vaccines and the other for dry goods. Information regarding maintenance and repair costs was not available for this analysis, suggesting that the actual baseline cost in Niger might exceed our current calculations.

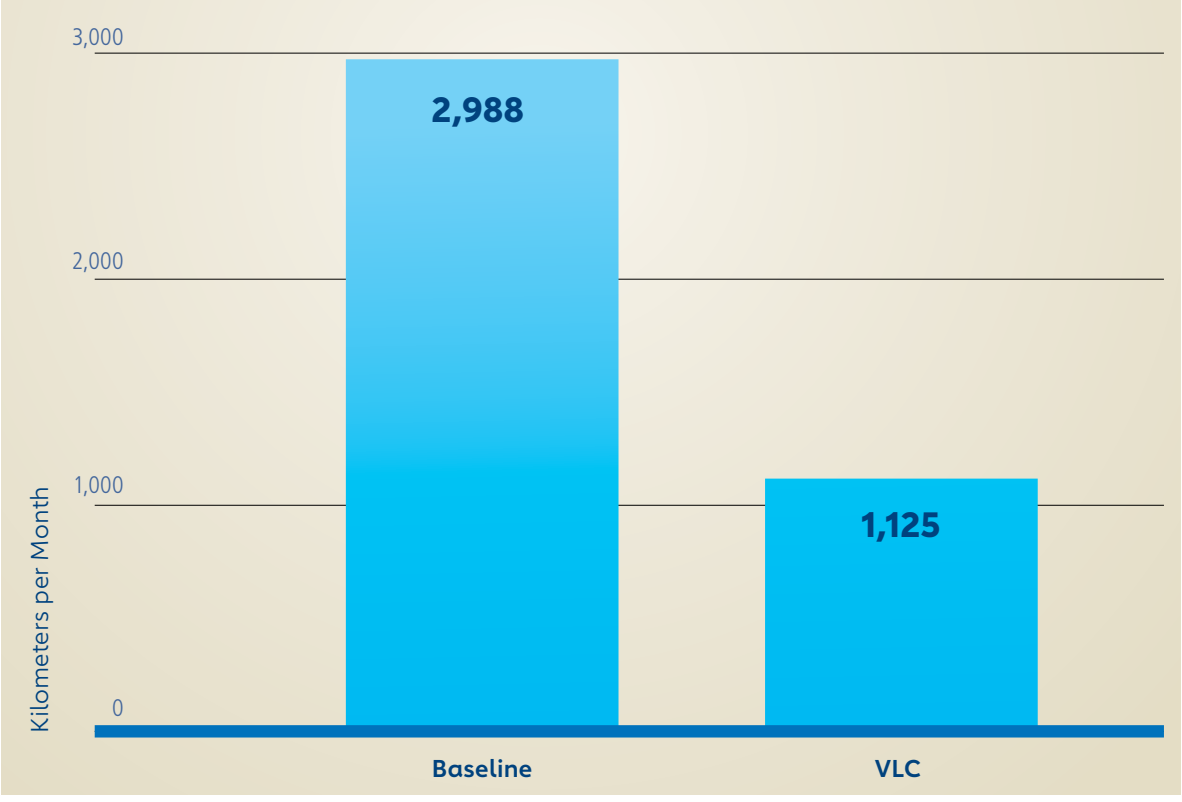
In the context of the Vaccine Land Cruiser, the major cost component is fuel consumption, which represents 74% of the overall transport cost per vaccine dose. The substantial cost difference between the conventional transport method and the Vaccine Land Cruiser can be attributed to two primary factors – **operational consolidation** and **route optimization**.

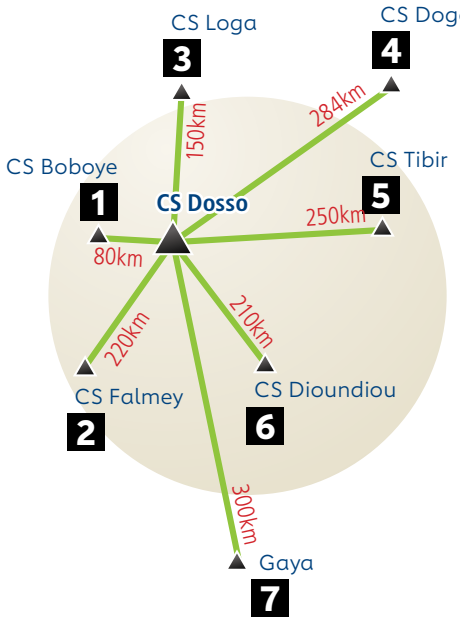
The conventional method, which utilizes two trucks – one for vaccines and the other for dry goods – travels an estimated 2,988 kilometers across seven routes to each district store in the Dosso region for a typical monthly vaccine distribution cycle. In contrast, the Vaccine Land Cruiser requires only four routes to service the same seven district stores, covering a significantly reduced total distance of 1,125 kilometers.

> **"Before, with the conventional truck, we had to do two rotations to distribute vaccines and then another to distribute the dry commodities. With this vehicle we can transport both at the same time."**
>
> **Mr. Harouna Dembo Mamadou**, Regional EPI Coordinator, Niger

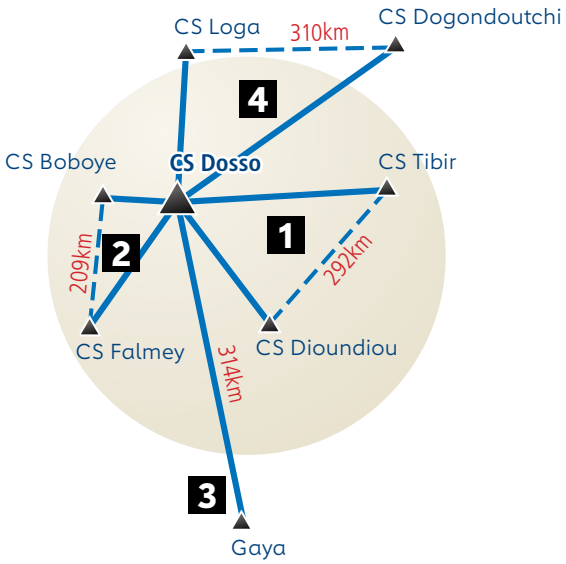
Hence, the Vaccine Land Cruiser offers considerable operational efficiencies by consolidating the vaccine and dry goods transportation into a single vehicle, coupled with an optimized routing plan for vaccine distribution. This streamlined approach significantly reduces total distance traveled and consequently, the fuel consumption, resulting in markedly lower transport costs per vaccine dose.

Niger: Distance Covered by Conventional Vehicle (Baseline) and Vaccine Land Cruiser for a Typical Vaccine Distribution Month





Baseline Distance = 2,988 km
(1,494 km × 2 trucks)



Optimized Distance = 1,125

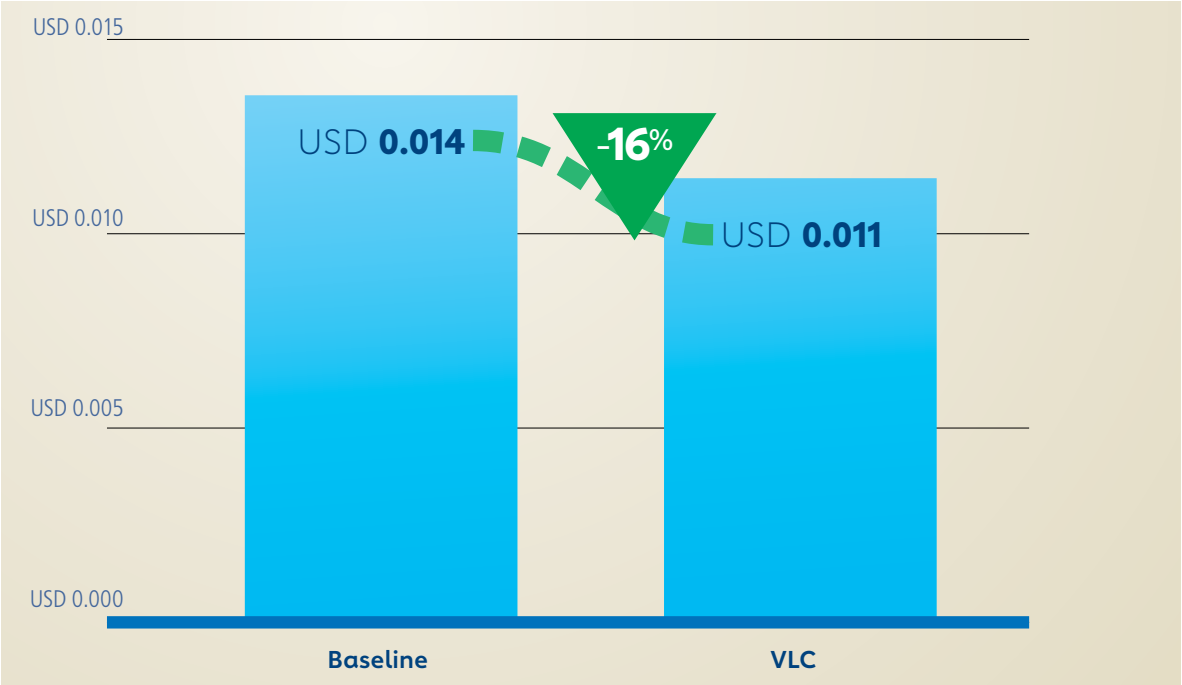
SENEGAL

In Senegal, the typical method for transporting vaccines from the Mobile Regional Supply Pharmacy (PRA) to health facilities in the Pété and Podor districts involved the use of a truck equipped with a locally constructed enclosed cabin. Vaccines, packed inside 23.3 liter PQS cold boxes with ice packs, were loaded onto the truck and transported to various health facilities. The PRA, an initiative from the National Supply Pharmacy (PNA), was designed to ensure the delivery of vaccines and medications to remote areas. In the case of the Vaccine Land Cruiser, the Saint Louis Regional Department of the Ministry of Health chose to utilize the vehicle for direct vaccine delivery to health facilities in the Pété and Podor districts. This decision was also intended to explore the potential for government-led vaccine deliveries.

Conventional Vehicle for Transporting Vaccines to Pété and Podor Districts, St. Louis Region Senegal

The baseline cost of delivering vaccines in Pété and Podor districts was calculated using vaccine transportation data provided by the Ministry of Health. For the nine health facilities that were inaccessible by the conventional vehicle, baseline costs were computed using commercial motorcycle transportation costs. The average baseline cost of transporting vaccines per dose to the 74 health facilities in Pété and Podor districts of the Saint Louis region stood at USD 0.014. In comparison, the Vaccine Land Cruiser had an average transportation cost per dose of USD 0.011. This equates to a 15.81% reduction in the cost of vaccine distribution, demonstrating the cost-effectiveness of the Vaccine Land Cruiser.

Senegal: Average Cost per Dose of Transporting Vaccines (Podor and Pété Districts)

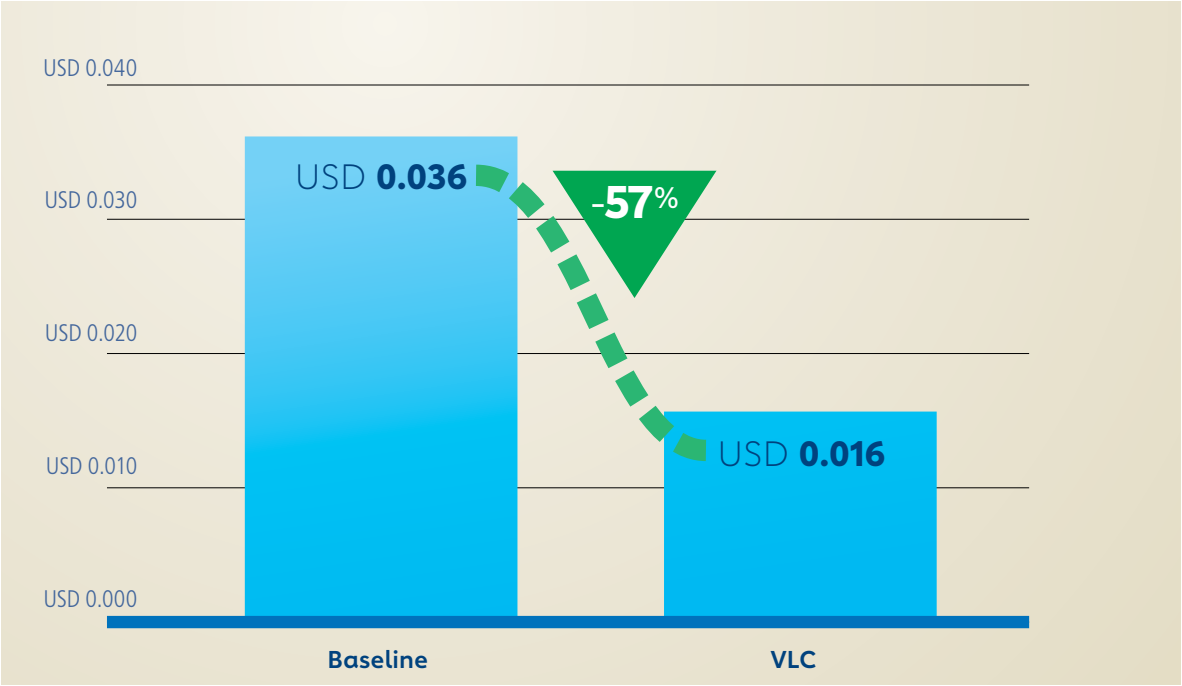


The baseline transport cost per dose in Senegal includes cost of fuel, fuel consumption per kilometer, distance per delivery route, and maintenance cost of CFA 125,000 (205 USD, at the official exchange rate/June 2023) per 10,000 kilometers. No significant changes were observed between the use of both the conventional vehicle and Vaccine Land Cruiser. Distribution of vaccines followed the same route for both vehicles with no significant differences between distances. The difference between the transport cost per dose can be attributed to the fuel efficiency of the Vaccine Land Cruiser and number of doses transported. The conventional vehicle had a fuel consumption of 15.00 liters per 100 kilometers while the Vaccine Land Cruiser consumed an average of 12.15 liters per 100 kilometers. The conventional vehicle transported 121,286 doses of vaccines compared to the Vaccine Land Cruiser that transported 232,438 doses of which 73,850 COVID-19 vaccines were transported in September 2022.

BURKINA FASO

In Burkina Faso, health facilities within the Léna district traditionally retrieved vaccines from the district store located in Léna. EPI health facilities' managers (most commonly nurses)received monthly transportation reimbursement for collecting vaccines on behalf of their respective health facilities. This transportation cost data was provided by the Burkina Faso Ministry of Health, which allowed for the calculation of the baseline cost per dose for vaccine transport. This was found to be USD 0.036. In comparison, the Vaccine Land Cruiser was able to transport vaccines at an average cost per dose of just USD 0.017. This equates to a significant reduction of 56.94% in the cost of transporting vaccines per dose, further highlighting the cost efficiency.t

Burkina Faso: Average Cost per Dose of Transporting Vaccines (Léna District)

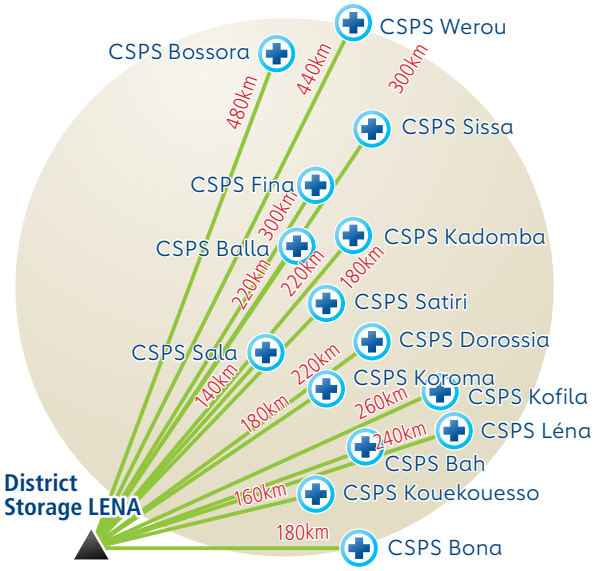


The baseline transport cost of transporting vaccines in Léna district of Burkina Faso was a fixed rate paid to EPI managers of the 16 health facilities on a monthly basis. The average baseline cost of transporting vaccines was USD 207.35 while the average cost of transporting vaccines with the Vaccine Land Cruiser was USD 120.60. More vaccines were also transported with the Vaccine Land Cruiser than with the conventional vehicle i.e. 71,081 and 57,335 respectively.

> **"Before, health center staff had to leave the center to collect the vaccines but now, the vehicle makes it easier to supply the CSPS (health centers)."**
>
> **Dr. Goumbane Nanimpo Birèmina**, Head Doctor of Léna District, Burkina Faso

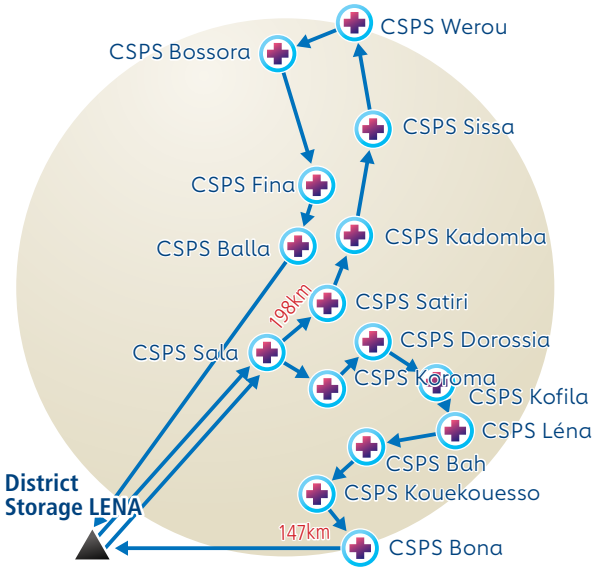
The immunization supply chain in the Léna district underwent a strategic transformation, transitioning **from a 'pull' system** – wherein health facilities were responsible for collecting their monthly vaccine supplies from the district store – **to a 'push' system**, where the district store actively delivered vaccines to all the health facilities. This change brought about benefits, including **significant cost savings, streamlining of the immunization supply chain, and considerable time savings for health workers**, who previously had to invest hours in the transportation of vaccines. Consequently, this liberated time could now be channeled into critical health services, further enhancing the overall efficiency and effectiveness of the district's healthcare system.

Conventional Method (Motorcycles)



Baseline Distance = 4,000 km

Vaccine Land Cruiser



Optimized Distance = 345 km

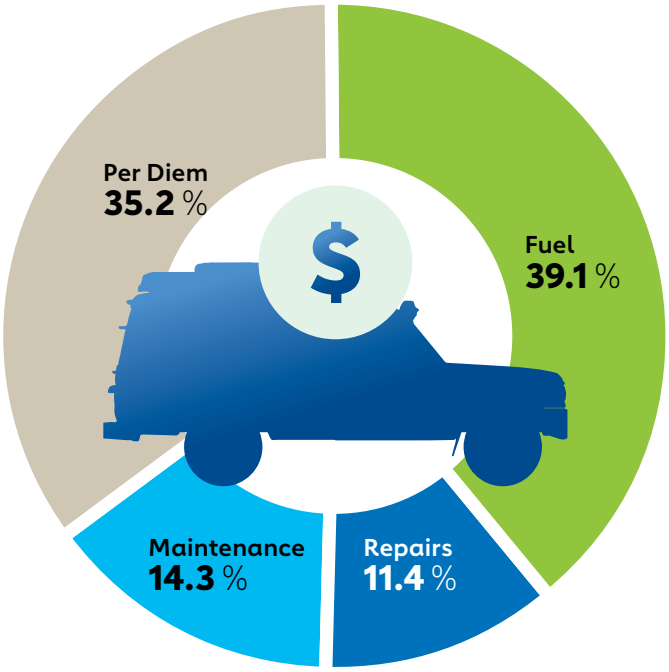
In summary, the implementation of the Vaccine Land Cruiser for the distribution of vaccines had a substantial impact on reducing costs in Niger, Senegal, and Burkina Faso. By examining the cost per dose of transporting vaccines, we observed an impressive cost reduction of 15% to 63% across these countries when using the Vaccine Land Cruiser. This highlights the significant value and efficiency of this innovation in the logistics of vaccine delivery. The Vaccine Land Cruiser has proven itself to be a cost-effective solution for distributing vaccines, particularly to cover hard-to-reach areas.

PROPORTION OF VACCINE LAND CRUISER OPERATIONAL COST FOR TRANSPORTING VACCINES

When evaluating the operational costs associated with the Vaccine Land Cruiser's vaccine transportation across Niger, Senegal, and Burkina Faso, it is evident that fuel and per diem payments constitute the majority of these costs. Fuel costs, accounting for 39% of the total operational cost, emerged as the highest proportion. This is not surprising given that the Vaccine Land Cruiser covered an extensive distance of over 27,157.50 kilometers, with an average fuel consumption of 12.98 liters per 100 kilometers.

Per diem payments, despite not being a factor in Burkina Faso, still comprised a significant 35% of the Vaccine Land Cruiser's operational cost. This reflects the considerable expense associated with compensating personnel involved in vaccine delivery.

Proportion of Vaccine Land Cruiser Operational Costs for Transporting Vaccines



Maintenance of the Vaccine Land Cruiser is another crucial aspect of operational costs. Managed by Toyota and performed by its subsidiary, Corporation for Africa and Oversea (CFAO), maintenance was conducted at 1,500 km, 5,000 km, and 10,000 km intervals. As of May 2023, the Vaccine Land Cruiser operating in Niger and Senegal had undergone maintenance at the 10,000 km interval.[8]

Overall, understanding the distribution of operational costs is critical for effective budgeting and planning in vaccine delivery. It also provides valuable insight into potential areas for cost reduction and efficiency improvements.

Table Showing Operational Costs of the Vaccine Land Cruiser

NIGER	
TOTAL	USD 7,748.34
FUEL	USD 1,555.70
MAINTENANCE	USD 525.97
REPAIRS	USD 0.00
PER DIEM	USD 5,666.67
TOLL CHARGES	USD 0.00

SENEGAL	
TOTAL	USD 2,988.11
FUEL	USD 1,168.63
MAINTENANCE	USD 427.95
REPAIRS	USD 340.25
PER DIEM	USD 1,051.28
TOLL CHARGES	USD 0.00

BURKINA FASO	
TOTAL	USD 1,176.97
FUEL	USD 917.12
MAINTENANCE	USD 235.23
REPAIRS	USD 29.06
PER DIEM	USD 0.00
TOLL CHARGES	USD 24.62

[8] Repair costs were also factored into the operational costs, albeit these were incurred in Senegal and Burkina Faso due to a faulty fuel filter, likely as a result of impure fuel. This incident underscores the importance of using high-quality fuel to avoid potential mechanical issues and associated repair costs.

Mrs. Hamidou Hadiza Ango, Regional EPI Deputy Coordinator, Niger.

Safe Delivery of Vaccines

Temperature records and damage of vaccine vials in transportation were used to analyze the safe delivery of vaccines in transportation using the Vaccine Land Cruiser. Temperature monitoring devices were placed in the Vaccine Land Cruisers to record the internal temperature of the refrigerator, ambient temperature (outside the refrigerator but inside the vehicle), and external temperature (outside the vehicle). In South Sudan, because it is a prospective cohort study, two temperature monitoring devices were placed in the cold boxes of the conventional vehicle.

Indicators used to monitor and evaluate the safe delivery of vaccines with the Vaccine Land Cruiser as well as the conventional vehicle are:

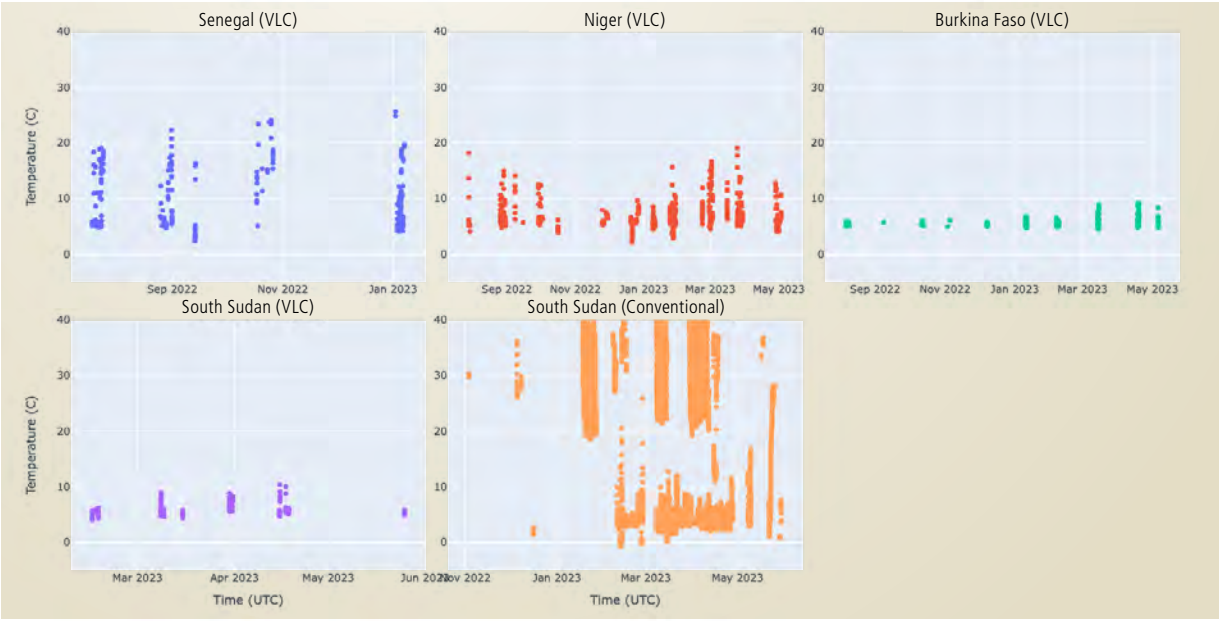
1. Temperature of vaccines in transportation
2. Number of vaccine vials/doses damaged from temperature excursion and breakage in transportation (baseline vs. Vaccine Land Cruiser)

Temperature of Vaccines in Transportation

Internal temperature records of vaccines in transportation varied across countries using the Vaccine Land Cruiser. In Burkina Faso, the internal temperature of vaccines for all vaccine deliveries remained relatively stable within the required temperature range of 2°C – 8°C. Internal temperature of vaccine deliveries in Niger and Senegal were characterized by temperature excursions outside the required temperature of 2°C – 8°C. Conversely, in South Sudan, the Vaccine Land Cruiser maintained a consistent temperature between 2°C – 8°C, with very few instances of high temperature excursions. The conventional vehicle, on the other hand, recorded instances of high and low temperature excursions.

> **"Here our biggest challenge is to transport vaccines guaranteeing quality, meaning keeping the temperature range from 2 to 8 degrees (...) the difference between this vehicle and a conventional vehicle is the autonomy. This vehicle allows us to power the refrigerator using its own batteries, connect it to an electrical source for charging, or utilize the vehicle's engine."**
>
> **Mrs. Hamidou Hadiza Ango**,
> Regional EPI Deputy Coordinator, Niger

Chart Showing Temperature of Vaccines in Transportation using the Vaccine Land Cruiser

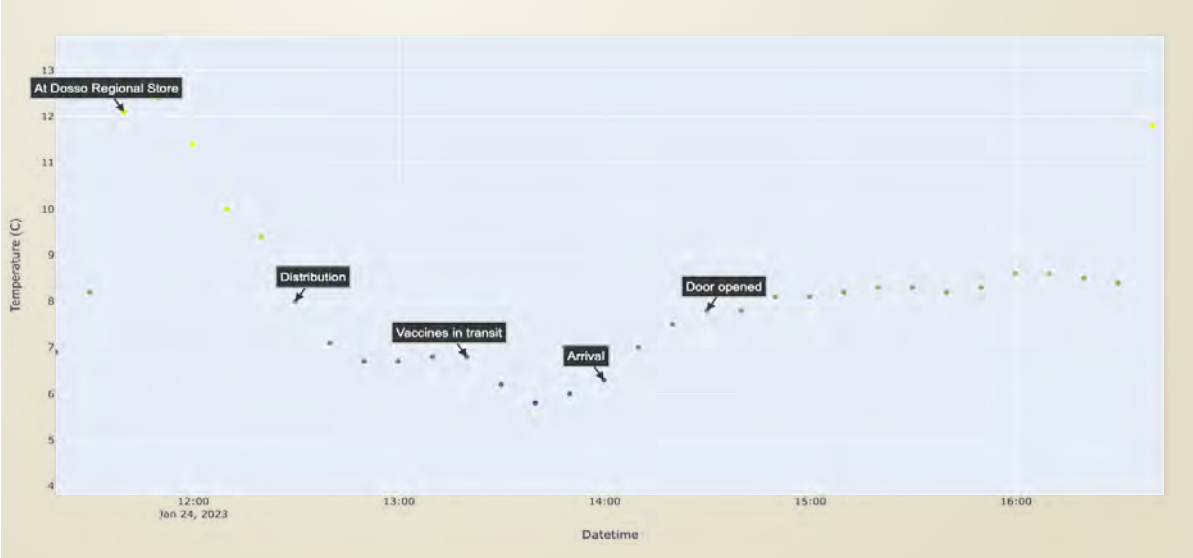


The table below summarizes the temperature records for each country:

Average Temperatures (°C)	BURKINA FASO	NIGER	SENEGAL	SOUTH SUDAN
VLC	**5.7**	**6.8**	**10.6**	**5.9**
Conventional Vehicle	NA	NA	NA	12.1

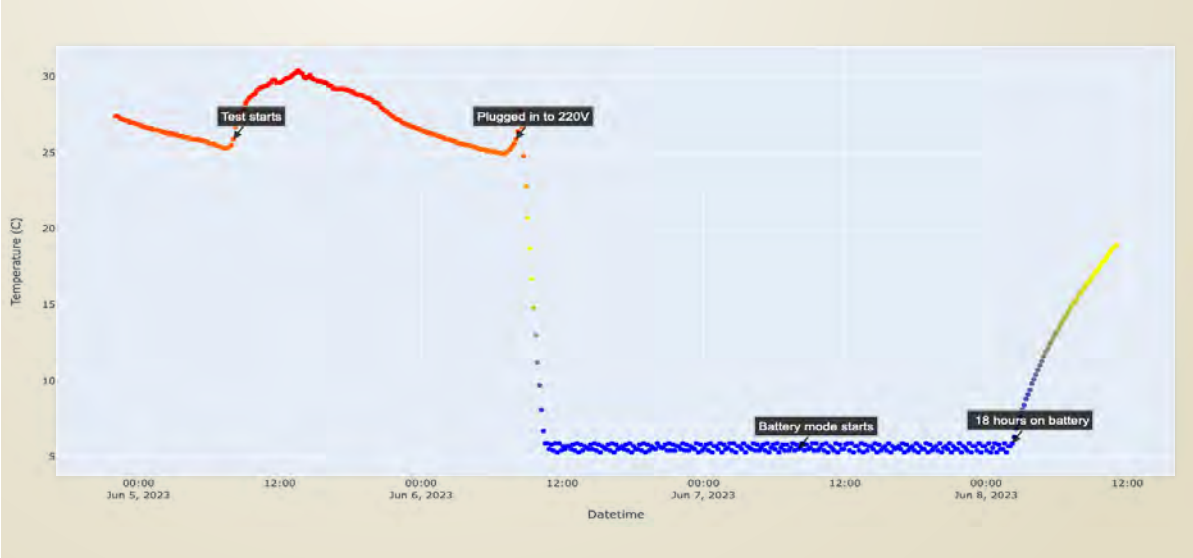
High temperature excursions observed in Niger, Senegal and South Sudan were primarily due to opening the refrigerator door during vaccine loading and on arrival at district stores (Niger) and health facilities (South Sudan). In Niger, these high temperature excursions aligned with the timeframes of vaccine packing at regional stores and arrival at distribution points.

Chart Showing Typical Vaccine Distribution in Dosso Region, **Niger**



An extensive number of high temperature excursions were recorded in Senegal, leading to a temperature test by B Medical Systems. The tests entailed 24-hour ambient temperature conditioning of the refrigerator, followed by another 24 hours of operation using 220V current. The refrigerator then continued to function on battery power. The test results indicated no manufacturing defects. However, several factors such as short travel distances, a faulty refrigerator battery, and improper handling of the temperature monitoring devices have been identified as potential causes of temperature fluctuations.

Chart Showing Temperature Test in **Senegal** Vaccine Land Cruiser Refrigerator



It is important to note that there have only been four vaccine distributions with the Vaccine Land Cruiser in Senegal since it began operation in August 2022. This is mainly as a result of a strike action by health workers from late January to May 2023. The factors identified above have not been fully mitigated to see the impact on temperature records.

Vaccine Doses Damaged

TEMPERATURE

Despite temperature excursions recorded in Niger and Senegal, no high temperature alarms (indicating 10 continuous hours of temperatures above 8°C) were triggered in any of the Vaccine Land Cruiser vehicles across the four countries. Consequently, no vaccines were reported to have been damaged following VVM changes. Neither were there any instances of low-temperature alarms, where the temperature falls below -0.5°C for an hour.

However, the conventional vehicle used in South Sudan recorded both high and low-temperature alarms.

Table Summarizing the Temperature Alarms in **South Sudan**

Vehicle	Distributions	Temperature Alarm Rates		Doses
		High	Low	
VLC	**7**	**0**	**0**	**41,124**
Conventional Vehicle	4	21	17	11,651

According to feedback received from the implementing partners operating the conventional vehicle in South Sudan, the following reasons were given:

1. The temperature excursions recorded were due to the door being left open after vaccine distributions
2. The highest temperature recorded was at 9.6°C while delivering vaccines with the conventional vehicle. This was due to opening of the cold box which contains packages for 2 health facilities in that only carrier, hence affecting the temperature.
3. Where the temperatures were lower than 2°C, the temperature monitoring device was placed on the ice packs.

BREAKAGE

Only one instance of vaccine vial damage was reported in the Vaccine Land Cruiser during transportation, which was a single measles diluent vial in Niger during the initial distribution on July 27, 2022. This damage was attributed to refrigerator tray shaking during transportation. To mitigate this, cold chain officers devised a method of placing cardboard objects at tray joints to minimize shaking.

To summarize, the Vaccine Land Cruiser provides a highly reliable means for vaccine transportation, demonstrating minimal risk of temperature damage to vaccines. With appropriate placement and handling of vaccines within the refrigerator, the likelihood of vaccine vial breakage is significantly mitigated. Thus, the Vaccine Land Cruiser emerges as a safe and effective solution for maintaining the integrity of vaccines during transport, ensuring they are delivered in the optimal temperature and condition.

First day school after holidays for the children of Agadez in the North of Niger. 2021. **© UNICEF/UN0535915/Dejongh**

Lessons Learnt

In this section, we evaluate key insights gathered from the implementation of the Vaccine Land Cruiser in the vaccine distribution process.

INITIAL HIGH TEMPERATURES

At the onset of vaccine distribution, initial high temperatures revealed that it takes approximately an hour for the refrigerator's temperature to drop from ambient levels to the optimal 2°C – 8°C range. This underscored the necessity of conditioning the refrigerator prior to loading vaccines.

TEMPERATURE EXCURSIONS DURING DISTRIBUTION

Temperature excursions during distribution highlighted the need for a more efficient handling process. This led to the pre-packaging of vaccines for each location before loading into the refrigerator.

ROUTE PLANNING

Efficient route planning emerged as a critical factor, especially when multiple locations were situated within short distances. This necessitated sufficient recovery time for the refrigerator to regain its optimal temperature.

REFRIGERATOR SPACE UTILIZATION

Lastly, we noted the varying utilization of refrigerator space, which was lower during deliveries to health facilities and higher at district stores. This insight guides us towards optimizing vaccine deliveries to reach more locations, including outreach or mobile sessions, thereby increasing the utilization of refrigerator space.

The subsequent table provides a concise summary of our experiences across the different countries involved in this initiative. For each observed event or cause, we outline the associated lessons learned, the corresponding actions taken or to be undertaken, and any changes required in the process moving forward. This systematic breakdown facilitates a clear understanding of the journey so far, and provides a valuable reference for improving vaccine distribution efficiency and effectiveness in the future.

Table Showing Lessons Learnt with the Corresponding Events and Actions Taken

Cause/Event	Lesson Learnt	Action	Process Change
High temperatures at the beginning of vaccine distribution	It takes around 60 minutes for the temperature of the refrigerator to reach 2C-8C from ambient/ external temperatures	Condition refrigerator before loading vaccines for distribution	Vaccine distribution
Temperature excursions during vaccine distribution	Counting vaccines at every location increases the internal temperature of the refrigerator	Pre-package vaccines for each location before loading into the refrigerator	Vaccine distribution
	Multiple locations within short distances apart (2 mins – 10 mins) require the refrigerator to recover to 2C – 8C	Route planning before distribution to allow refrigerator to recover to stable temperatures	Planning
Low utilization of refrigerator space	Deliveries to health facilities have low refrigerator storage space utilization while deliveries to district stores have high refrigerator storage space utilization	Optimizing vaccine deliveries to health facilities to reach more locations, outreach or mobile sessions	Planning

Offloading of vaccines at a district store in Dosso Region, Niger 2023. **Frame extracted from the video recording by the videographer (Hassane)**

Vehicle Improvements

Regular interactions were held between Gavi, Toyota, B Medical Systems, and the project team to discuss feedback from the country teams operating the vehicles. Based on this feedback, Toyota and B Medical Systems incorporated several enhancements into the Vaccine Land Cruiser for current and future models. These include:

1. Shipment of the vehicle with the refrigerator's batteries disconnected to avoid deep discharge due to long shipment time (Toyota Nagoya and CPS Antwerp)
2. Prepare an SOP with clear instruction on connecting refrigerator's batteries and pre departure check-up at the Toyota local dealer (Toyota)
3. Adding a voltage/ battery level meter to ease the management and information on batteries' level (B Medical Systems)
4. Replacing metallic shelves by independent closed drawers to reduce impact on temperature changes due to opening of the door (B Medical Systems)
5. Adding a fuel-water separator and additional fuel filter, to prevent damages caused by bad quality fuel (Toyota Nagoya and CPS Antwerp)
6. Adding 2 foldable seats between refrigerator and front seats, capacity up to 4 passengers (Toyota Nagoya and CPS Antwerp)

Children at the playground of their school in Niamey, the capital of Niger, 2021. **© UNICEF/UN0439611/Dejongh**

Recommendations

After thorough evaluation of the Vaccine Land Cruiser across Niger, Burkina Faso, Senegal, and South Sudan, the following recommendations are provided to enhance the initiative's impact on immunization supply chain access, efficiency, and safety.

1. The Vaccine Land Cruiser should be adopted and its use expanded in the vaccine distribution process. The Vaccine Land Cruiser has demonstrated **significant cost-saving potential**, with a reduction in the cost per dose for vaccine transportation recorded across Niger, Senegal, and Burkina Faso. Its consistent temperature control ensures vaccine potency, contributing to improved health outcomes.

2. The onset of vaccine distribution revealed **the necessity of pre-conditioning the refrigerator prior to loading vaccines**, since it takes about an hour for the refrigerator to cool down from ambient temperature to the optimal range of 2°C – 8°C. It is recommended that this process be standardized across all countries to ensure that the vaccines are always stored within the appropriate temperature range from the onset of their journey.

3. Temperature excursions during the distribution process highlighted the need for more efficient handling of vaccines. As a result, **pre-packaging vaccines for each location** before loading into the refrigerator is recommended. This strategy can streamline the loading and unloading process, minimize the frequency and duration of the refrigerator door being open, and hence maintain optimal temperature within the refrigerator.

4. **Effective route planning was identified as a crucial factor** in ensuring that the Vaccine Land Cruiser can maintain its optimal temperature, particularly when deliveries are made to multiple locations within short distances. Adequate recovery time for the refrigerator to regain its optimal temperature after each delivery should be factored into the route planning process.

5. The data showed varying utilization of refrigerator space during vaccine deliveries, which was lower during deliveries to health facilities and higher at district stores. This suggests that **more leeway to optimize the distribution strategy** to reach more locations, including outreach or mobile sessions, thereby maximizing the use of the Vaccine Land Cruiser and the refrigerator space.

6. **Regular maintenance should be a priority**, and conducted at the recommended intervals to ensure the longevity and operational efficiency of the Vaccine Land Cruiser. Additionally, the use of high-quality fuel should be mandatory to prevent mechanical issues and unwanted repair costs, as experienced in Senegal and Burkina Faso.

7. To maximize the benefits of the Vaccine Land Cruiser, **cold chain staff should be properly trained** on the best practices for loading and unloading vaccines, as well as maintaining the Vaccine Land Cruiser's refrigeration system. This will help to prevent potential vaccine damage and extend the lifespan of the vehicle.

8. **Consistent data collection and monitoring** should be in place to track the performance of the Vaccine Land Cruiser over time. This would provide necessary information for periodic evaluations and strategy adjustments.

9. To continuously improve the use and operation of the Vaccine Land Cruiser, **the establishment of a Community of Practice (CoP)** among the participating countries is recommended. This CoP would serve as a platform for country teams to share their experiences, challenges, and success stories.

In conclusion, the Vaccine Land Cruiser holds significant potential for improving the cost-effectiveness and efficiency of vaccine distribution in regions with challenging terrain and harsh climatic conditions. It is recommended that its use be further explored and expanded upon, with a focus on cost management, maintenance, capacity building and optimization of supply routes based on its capacity.

Offloading of vaccines by Mrs. Hamidou Hadiza Ango at a district store in Dosso Region, Niger 2023. **Frame extracted from the video recording by the videographer (Hassane)**

Discussion and Further Opportunities

The implementation and evaluation of the Vaccine Land Cruiser project have unraveled the potential to **transform the system design of healthcare supply chains**. While the study mainly focused on vaccine delivery, this vehicle presents broader programmatic opportunities that can significantly impact healthcare delivery.

One such opportunity is the **bundling of vaccine delivery with other essential medical goods** like insulin, biologics, diagnostic reagents, blood products, or oxytocin. Leveraging the efficiency and reliability of the Vaccine Land Cruiser, multiple medical goods can be transported together, creating a comprehensive and integrated approach to healthcare delivery. This not only enhances routine immunization but also improves access to comprehensive care, especially in remote and underserved areas.

The real-time tracking capabilities of the Vaccine Land Cruiser **allow for precise and targeted vaccine deliveries to areas with the highest demand**. It facilitates swift responses to disease outbreaks and enables the organization of timely and effective vaccination campaigns. Additionally, the vehicle's mobility allows for **vaccination service delivery to people on the move**, such as displaced populations and nomadic communities.

> **"The Land Cruiser has facilitated the work in health centers and villages where we do the mobile vaccination (..) we consider it a great moment for us."**
>
> **Ms. Natalia Daniel**, Primary Healthcare Logistics Supervisor, South Sudan

Furthermore, the integration of **reverse logistics** into the supply chain is a valuable feature of the Vaccine Land Cruiser. As it navigates through challenging terrains, the vehicle can collect waste, such as used vials, syringes, and personal protective equipment, promoting environmentally responsible waste management practices.

In conclusion, beyond its immediate impact on vaccine distribution, the Vaccine Land Cruiser holds the potential to transform healthcare supply chains, driving progress towards comprehensive care and equitable access to essential medical goods. By exploring this innovative approach and fostering collaborative and agile scaling efforts, countries can build more resilient, sustainable, and inclusive healthcare systems. To fully realize the transformative power of the Vaccine Land Cruiser, continued exploration, investment, and cross-sectoral partnerships are essential to optimize healthcare delivery in regions facing logistical challenges.


Ms. Natalia Daniel,
Primary Healthcare Supervisor

Annex 1 The Toyota Vaccine Land Cruiser

The Toyota Land Cruiser 78 series is a flagship Toyota model for many non-governmental organizations which include the United Nations. It is well known for its rigidity and ruggedness in traversing difficult terrain. The Toyota Land Cruiser 78 series serves as the base vehicle. Its rear compartment has been customized to accommodate the vaccine refrigerator. Roof rack fitted at the top of the vehicle can be used to load dry commodities during transportation.

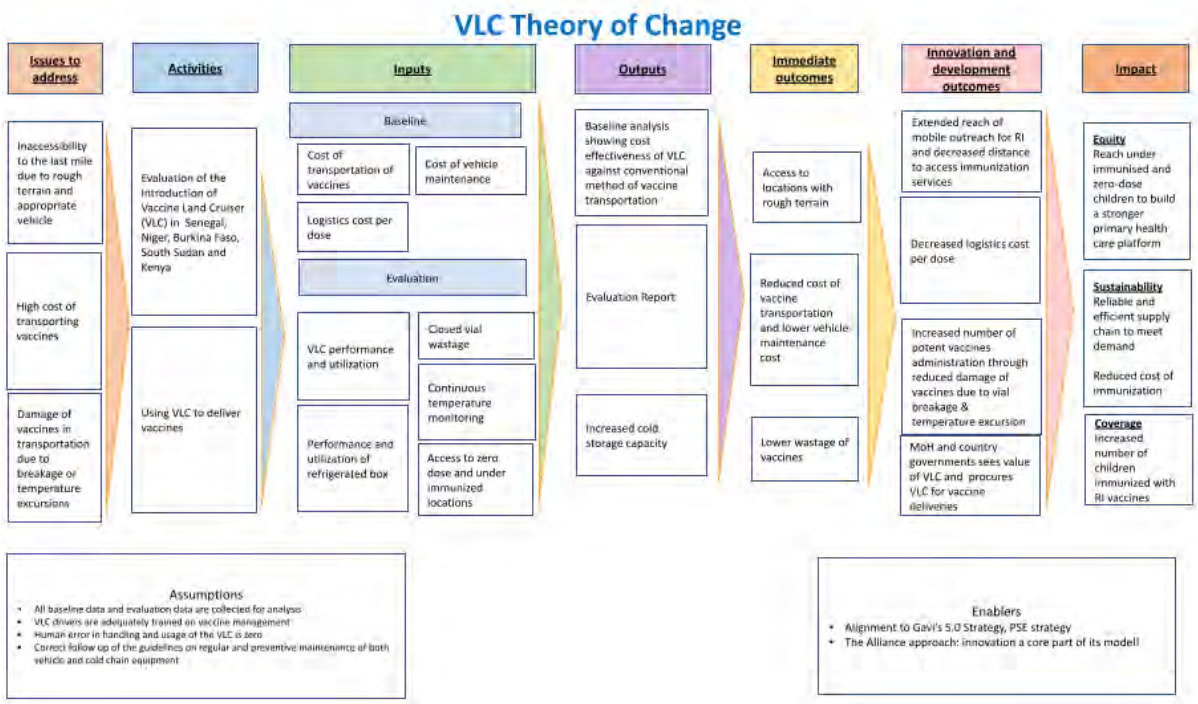
Other features of the vehicle includes:

The refrigerator is equipped with **B Medical Systems' CF850** vaccine refrigerator which has a net storage capacity of 396 liters and a temperature range of 2°C – 8°C.

Other features of the refrigerator includes:

- Rotational molded cabinet and adjustable shelves
- 230VAC & 12VDC connection – providing flexible operation alternatives
- Integrated 2 x 12V DC battery & charger
- Battery guard – Preserves refrigerator battery from complete discharge
- Digital temperature control for accurate temperature setting
- Forced air ventilation
- Door contacts (to cut off evaporator fan), visual and audible alarms
- Crash tested according to ECE R80 74/408/EWG

Annex 2 Vaccine Land Cruiser Theory of Change



Annex 3
Testimonials

BURKINA FASO

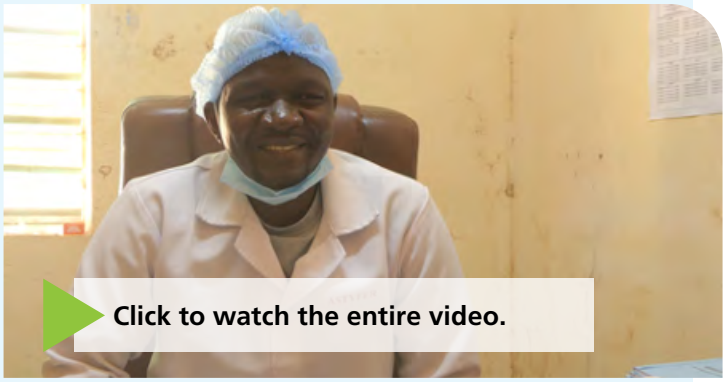
Mr. Sawadogo N. Isidor
Léna District Supply Chain Manager

"The vaccination has many challenges, being the major the geographical access. The road conditions are a challenge for us to surpass and supply vaccines to the health centers and to the follow up activities. There's big holes and rivers that needs to be overcome."

"It's a special vehicle, robust, and adapted to the local conditions and comparing to a normal 4x4 vehicle, it has fitted a refrigeration unit that allows us to have a continuous control and monitoring of the temperature from the loading of vaccines at district store until offloading at the health centers. This assures the quality of the vaccines delivered to vaccinate children."

Mr. Nabaloum Ambroise
Head Nurse at Sissa Health Post (Léna District)

"The challenges are innumerous. There's the road access, that presents some challenges and the lack of equipment that limits our activities."

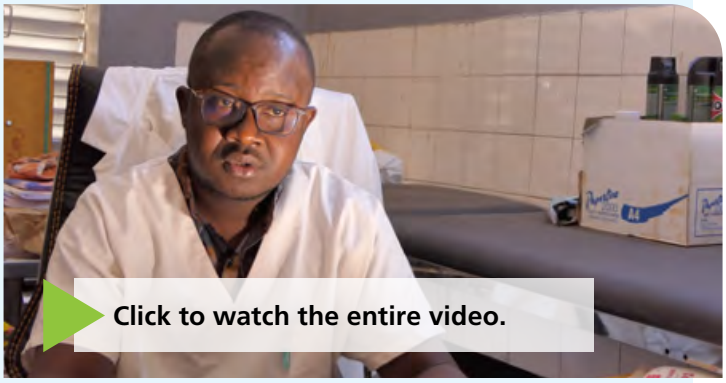


"Since we had the news that we have a new vehicle that will deliver us vaccines, we were very happy, because in particular during the rainy season, which is not an easy season, the vehicle allows to deliver vaccines with a good preservation status and quality control."

Mr. Gué Gautier

Head Nurse at Werou Health Post (Léna District)

"The biggest challenge, as you may have noticed, it's a hard-to-reach location, in particular during the rainy season. This is the season with major challenges, when doing vaccination campaigns."



"Since this vehicle started to deliver us vaccines, we never had a stockout, and it allows us to save on time and money. Why? Because before, it had to be us going to get the vaccines at the district. And now, having the vehicle to deliver us the vaccines, it's less a problem to sort out."

Dr. Goumbane Nanimpo Birèmina

Head Doctor of Léna District

"The challenge is mainly the geographic access, as you may have noticed, there are no direct ways to get to the health centers, and adding to that we have the current security context."

"The refrigerated vehicle came to help the district to supply vaccines, since before, it was the health centers who would come to get the vaccines' supply at the district and go back."

"We can say that the vehicle has great utility, it eases many aspects, and being an All-road vehicle, it can be used in rough terrain to reach the health centers."

"I think that this pilot went very well, although in the beginning it was a bit difficult, since the refrigerated vehicle is all automated, electronic, that we were not used to, but after the first field travel, we were more prepared to plan accordingly for the next distributions."

"The utilization of the refrigerated vehicle had many advantages, because it minimized the prior risks of having the health centers coming to get their vaccines' supply at the district."

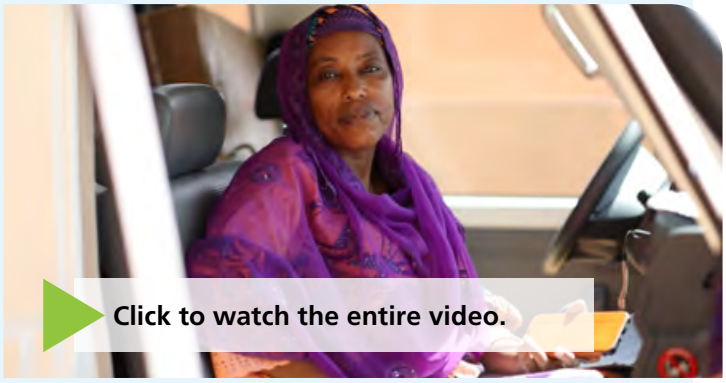
NIGER

Mr. Amadou Maitchibi
Dosso Regional EPI Driver

"The major challenge is the road condition, but has it is an All-road vehicle I can go anywhere with no major problems."

"Right now the vehicle's engine is on, the refrigerator is working, and when I arrive to Dioundiou (next district store) I'll keep the engine running or I can even turn it off. If there is electricity at Dioundiou, I can even charge the refrigerator's batteries before proceeding to Tibiri (next district store)."

Mrs. Hamidou Hadiza Ango
Regional EPI Deputy Coordinator

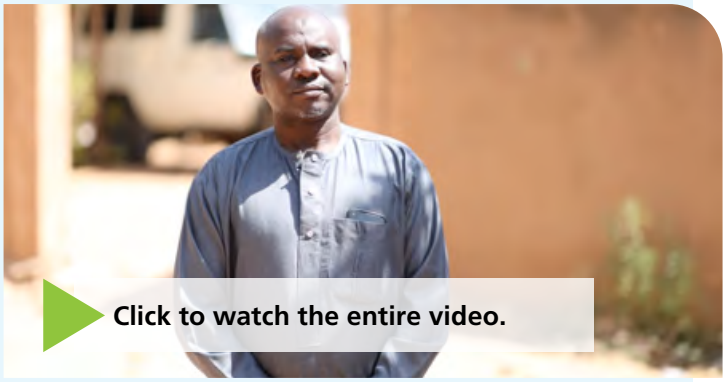


"Here our biggest challenge it's to transport vaccines guaranteeing quality, meaning keeping the temperature range from 2 to 8 degrees."

"The difference between this vehicle and a conventional vehicle is the autonomy. With this vehicle it's possible to operate the refrigerator with its own batteries, to plug it to the electricity to charge or to simply use the vehicle's engine. Adding to this we can transport not only the vaccines but all dry commodities. There's also a lower cost of the distribution of vaccines since we can do (cover) more than one district store per day."

Mr. Harouna Dembo Mamadou
Regional EPI Coordinator

"The challenge is to transport the vaccines within the right temperature."

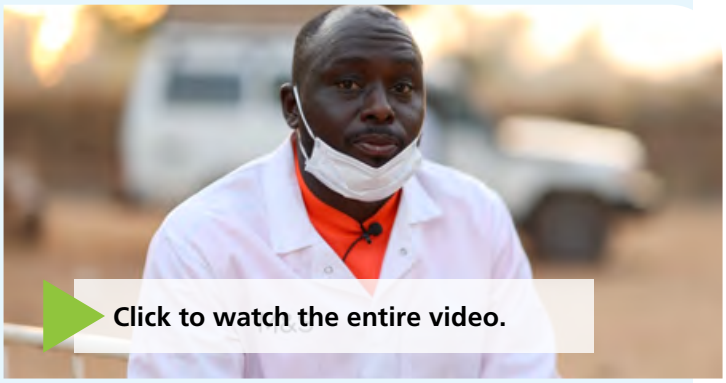


"This vehicle really brings us many advantages. First, it is well adapted to the road conditions at Dosso's region, second is it's capacity of producing cold, it can do it on battery mode, with regular electricity and with the vehicle's engine."

"Before, with the conventional truck, we had to do two rotations to distribute vaccines and then another to distribute the dry commodities. (..) With this vehicle we can transport both at the same time. (..) This way, we can supply two districts in the same day. (..) This has resulted in a reduction of the transportation cost."

Mr. Issoufou Diko
Dioundiou District EPI Coordinator

"Now it is possible that the vehicle with the vaccines stays overnight at the district. Even if the vehicle's engine is not on, it is possible to connect it to the electricity to charge the batteries."



"With different power sources, battery, engine, electricity, it is possible to guarantee that the temperature doesn't go up."

SOUTH SUDAN

Ms. Natalia Daniel
Primary Healthcare Supervisor

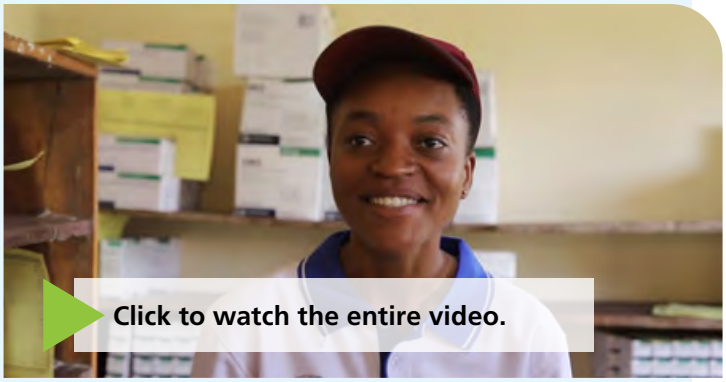
"The Land Cruiser has facilitated the work in health centers and villages where we do the mobile vaccination...we consider it a great moment for us."

Ms. Faida Jovanna Albino
Medical Logistics Officer

"Our biggest challenge is the road..."

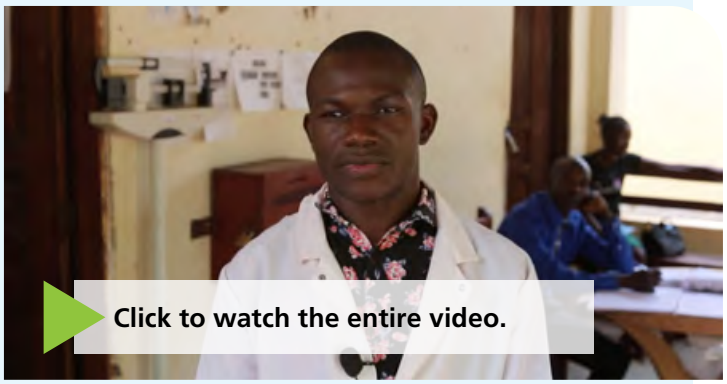
"It's going on well... the vaccine is safe in the car, in the fridge, it reaches here in good quality."

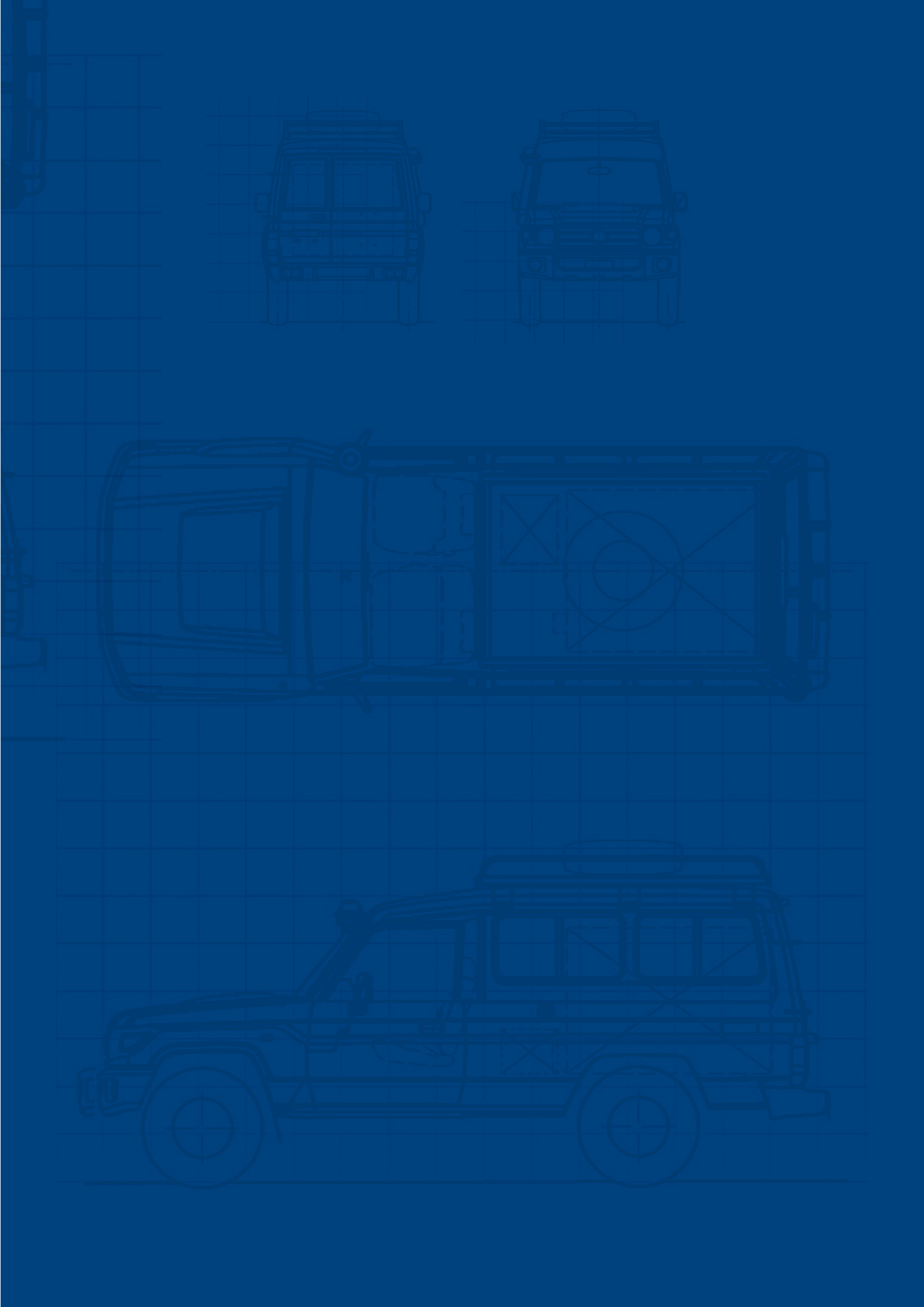
"The vehicle should continue, it's easy for us to use it and it's better than carrying on motorbike..."

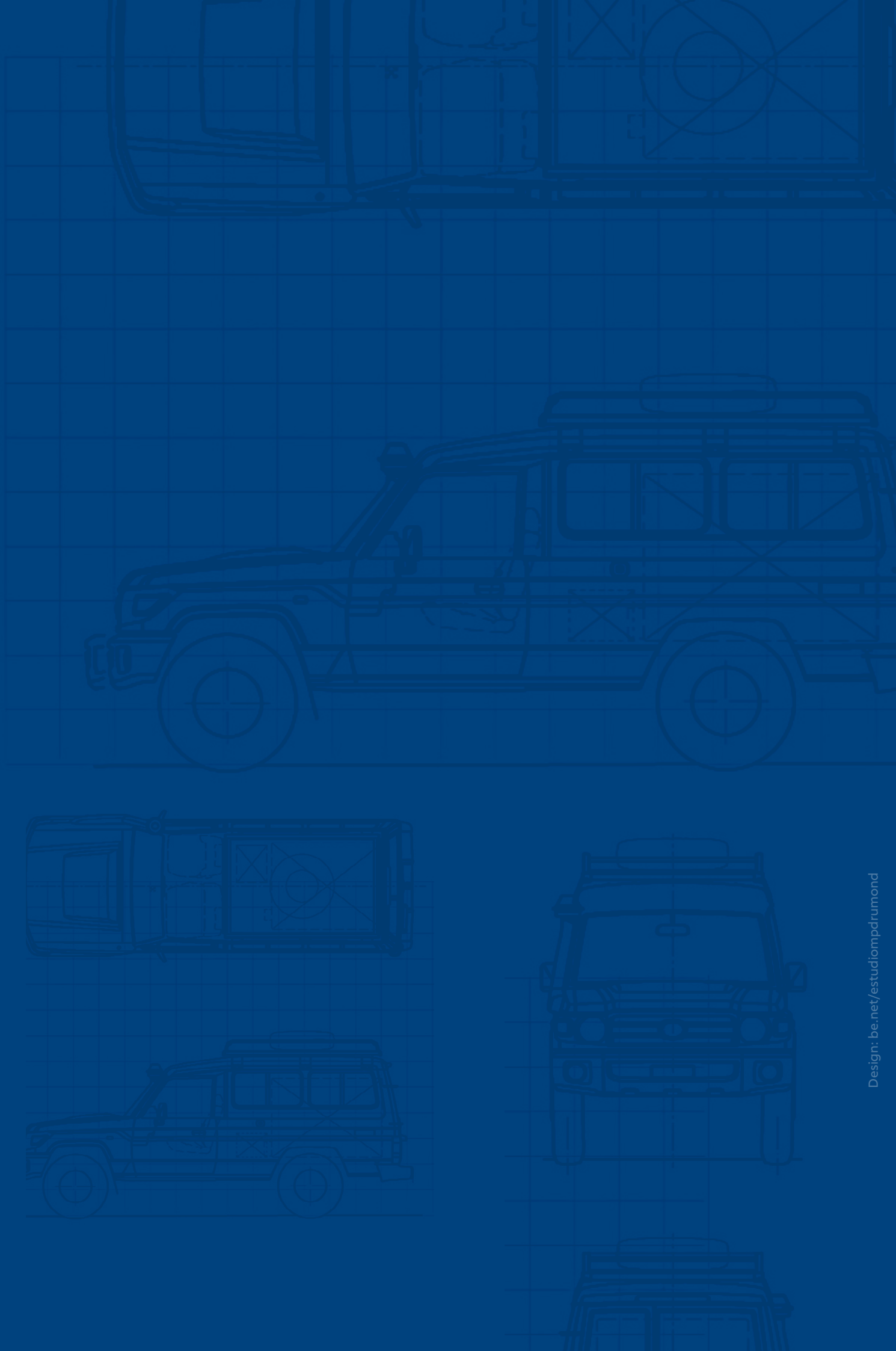


Mr. Joseph Moses Toro
Nurse Nangbimo PHCU

"I think now it's better using this Land Cruiser because before we were riding bicycles to transport vaccines."







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