OPTIMIZE

Vietnam
Report

OPTIMIZE Immunization systems and technologies for tomorrow

PATH

World Health Organization

This report was commissioned by Optimize: Immunization Systems and Technologies for Tomorrow, a collaboration between the World Health Organization and PATH. The report was authored by team members from PATH and the office of the National Expanded Programme on Immunization, National Institute of Hygiene and Epidemiology in Vietnam.

Contact information:

Joanie Robertson
Technical Officer
PATH
jrobertson@path.org

PATH addresses:

Mail
PO Box 900922
Seattle, WA 98109 USA

Street
2201 Westlake Avenue, Suite 200
Seattle, WA 98121 USA

www.path.org

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ACRONYMS

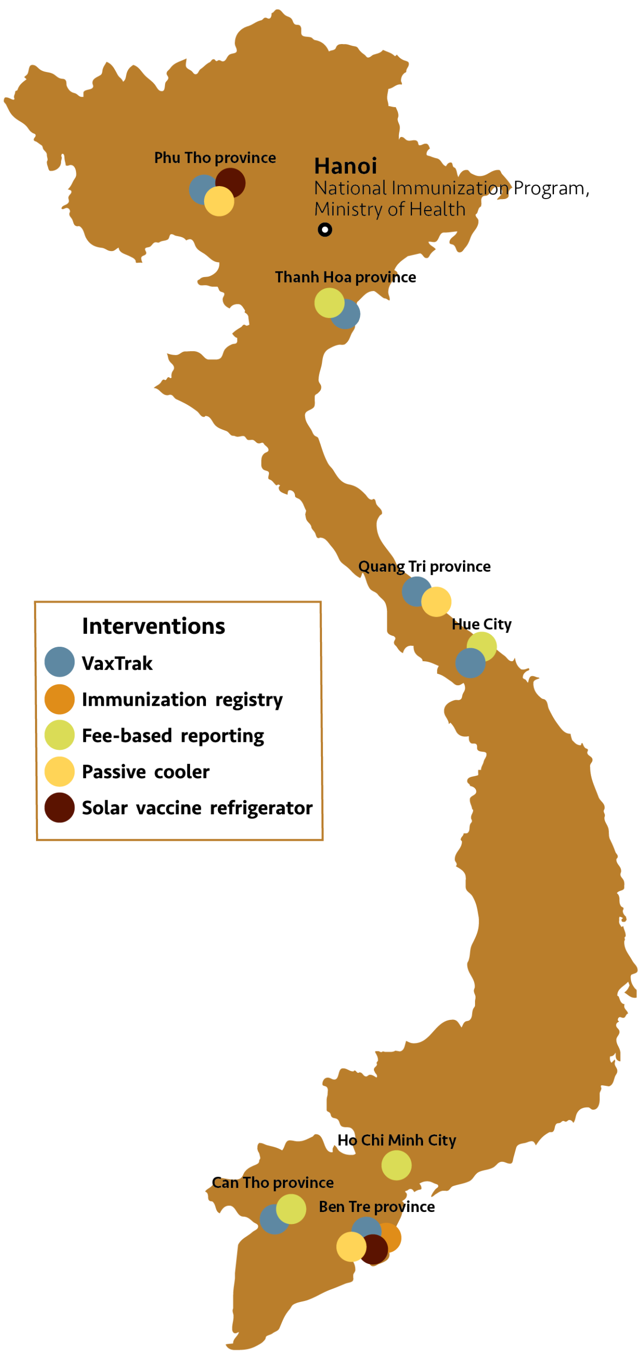
The following acronyms are used in this document.

AEFI	adverse event following immunization
BCG	bacillus Calmette-Guérin
CHC	commune health center
DTP	diphtheria-tetanus-pertussis
EPI	Expanded Programme on Immunization
EVM	Effective Vaccine Management
GDPM	General Department of Preventive Medicine
HepB	hepatitis B
IR	immunization registry
IT	information technology
MOH	Ministry of Health
NEPI	National Expanded Programme on Immunization (Vietnam)
NIHE	National Institute of Hygiene and Epidemiology (Vietnam)
PATH	Program for Appropriate Technology in Health
PMC	preventive medicine center
SMS	short message service
SOP	standard operating procedure
TB	tuberculosis
TT	tetanus toxoid
VVM	vaccine vial monitor
WHO	World Health Organization

MAP OF OPTIMIZE INTERVENTIONS

The locations of the five Optimize demonstration projects described in this report are shown on the following map of Vietnam.

Figure 1. Location of Optimize demonstration projects



1. INTRODUCTION

Overview

This report presents the results of demonstration projects and other activities undertaken in Vietnam as part of a partnership between project Optimize and Vietnam's Ministry of Health (MOH).

Between 2010 and 2012, Optimize collaborated with Vietnam's National Institute of Hygiene and Epidemiology (NIHE) and the General Department of Preventive Medicine (GDPM) to demonstrate innovations in the supply chain that can help the national immunization program to meet the demands of an increasingly large and costly portfolio of vaccines. This report describes the five demonstration projects undertaken in Vietnam as part of the collaboration.

1. A computerized system for tracking vaccine stock and reporting aggregated monthly immunization data.
2. A paper-based and computerized system for aggregated reporting of fee-based immunization services.
3. Computer- and mobile phone-based technologies for tracking children due for immunization and recording the immunizations given to them on an individual basis.
4. A new passive-cooling device for storing vaccines in commune health centers (CHCs).
5. New direct-drive solar refrigerators for storing vaccines in district health centers.

In addition, the following project activities are also described:

- Conducting the World Health Organization (WHO) Effective Vaccine Management (EVM) assessment.
- Developing standard operating procedures.
- Working with a local vaccine manufacturer on initial steps toward adopting vaccine vial monitor (VVM) technology for locally produced vaccines.

About project Optimize

Project Optimize is a five-year partnership between WHO and PATH to identify ways in which supply chains can be optimized to meet the demands of an increasingly large and costly portfolio of vaccines.

Optimize works directly with national governments and other institutions to identify problems in the supply chain and test innovative solutions. We also work with vaccine manufacturers and policymakers to help ensure that new products and policies enable supply chain systems to function effectively. Our goal is to help define an ideal vaccine supply chain that can be used to develop stronger, more adaptable, and more efficient logistics systems, extending the reach of lifesaving health technologies to people around the world.

For more information, please visit the Optimize website:

PATH: www.path.org/projects/project-optimize
WHO: www.who.int/immunization_delivery/optimize

1.1. Finding more information

In 2013, Optimize will publish comprehensive information on the demonstration projects and other initiatives it has been involved in. To view a full list of the resources that Optimize has published to document its work in Vietnam, please refer to the Vietnam resources page of the Optimize website. This is available on both PATH's and WHO's websites.

PATH: http://sites.path.org/vietnam/

WHO: www.who.int/immunization_delivery/optimize/vietnam

You can also find these documents, as well as detailed information on other innovations relating to vaccine supply and logistics systems, on the TechNet21.org website.

www.technet21.org

1.2. Contact details

Table 1 provides the details of companies and people who can be contacted about the interventions described in this report.

Table 1. Intervention contact details

Subject	Contact details
Computerized vaccine tracking and immunization reporting (VaxTrak)	For more information on ANZ Solution: www.anzsolution.com Or email Mr. Dau Duc Hai, Director, ANZ Reporting: dauduchai@anzsolution.com
Fee-based immunization reporting	Dr. Phan Trong Lan, Deputy Director General, Department of Preventative Medicine, MOH: ptlan2000@yahoo.com
	For more information on ANZ Solution: www.anzsolution.com Or email Mr. Dau Duc Hai, Director, ANZ Reporting: dauduchai@anzsolution.com
Digital immunization registry	For more information on iBase Company: www.ibase.com.vn Or email Mr. Luu Van Hai, Director: hai@ibase.com.vn

Subject	Contact details
Passive cooling at CHCs	More information on the Nano-Q cold box can be found on the Savsu website: www.savsu.com Or email Bruce McCormick, President, Savsu: b.mccormick@savsu.com.
Direct-drive solar refrigerators	More information on the Sure Chill® solar refrigerator can be found on the True Energy website: www.trueenergy.com Or email Ian Tansley, Director, True Energy: ian.tansley@trueenergy.com

Abbreviations: CHC = commune health center; MOH = Ministry of Health.

For all other questions, please contact the following people:

- Joanie Robertson, Technical Officer, PATH (jrobertson@path.org).
- Dr. Nguyen Van Cuong, Deputy Director, National Expanded Programme on Immunization, NIHE (tcmr.qg@gmail.com).

2. VIETNAM IN CONTEXT

2.1. The immunization system

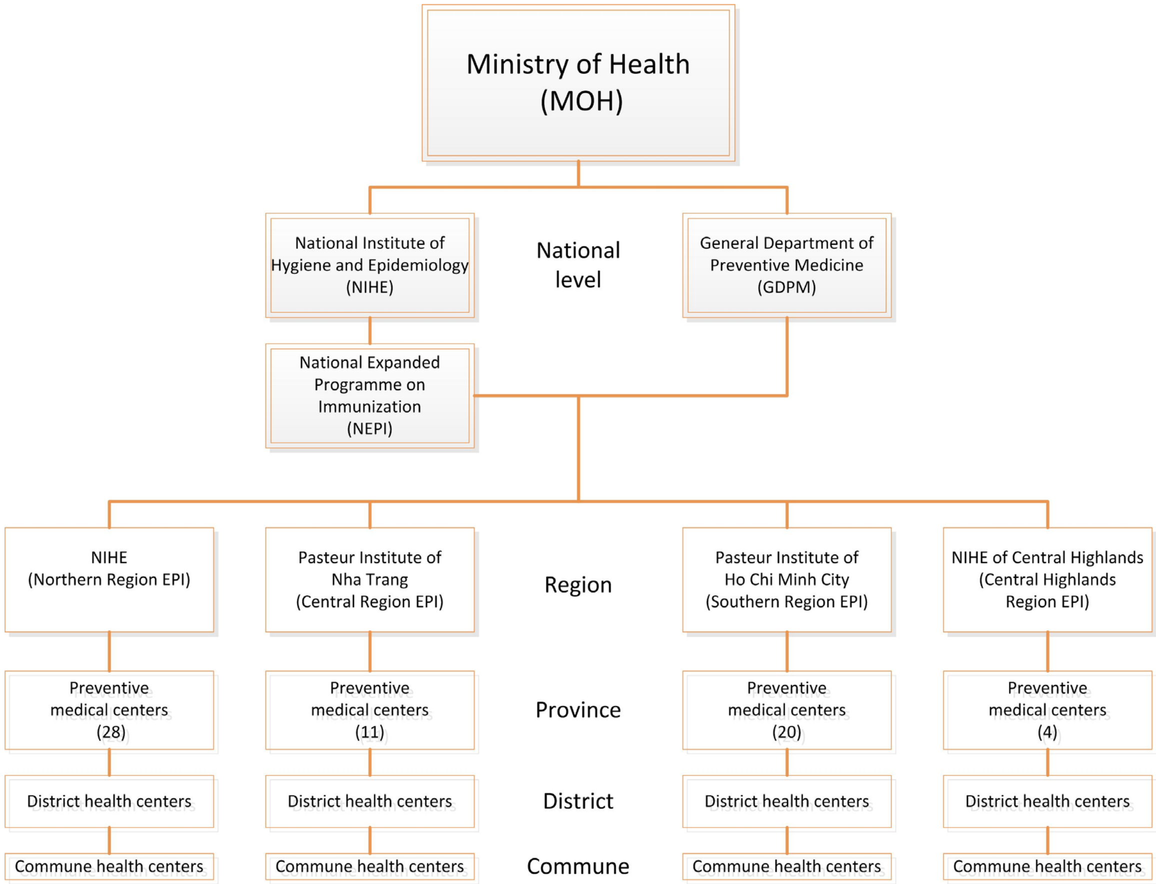
Vietnam's National Expanded Program on Immunization (NEPI) began in 1981. At that time, the program faced numerous difficulties, including poor transportation and communication infrastructure, little public awareness about the benefits of immunization, austere health facilities, and severe budget limitations. Since then, Vietnam's NEPI has overcome many of these challenges and achieved promising results. By 1985, NEPI had expanded to 100 percent of communes in the country and introduced six vaccines against dangerous infectious diseases (bacillus Calmette-Guérin [BCG] for tuberculosis [TB], diphtheria, pertussis, tetanus, measles, and polio). Since 1993, immunization coverage for children less than one year old has consistently exceeded 90 percent. Vietnam reached the international commitment of polio eradication in 2000 and neonatal tetanus elimination in 2005. With support from the GAVI Alliance, hepatitis B (HepB) vaccine was introduced in 2001, and diphtheria-tetanus-pertussis (DTP) was replaced by pentavalent DTP-HepB-*Haemophilus influenzae* type b in 2010, bringing the total number of vaccines in the schedule to eight. Vietnam has applied for GAVI funding to support the introduction of a rubella vaccine in the form of measles-rubella in 2013, and a tetanus-diphtheria booster for 7- and 15-year-olds is planned for introduction in 2014.

Important organizations in the Vietnamese immunization system include:

- The General Department for Preventive Medicine at the Ministry of Health, which oversees the provincial departments of health.
- The National Expanded Program on Immunization, part of the national Institute for Hygiene and Epidemiology.
- The provincial preventive medicine centers (PMCs) responsible for overseeing the Expanded Programme on Immunization (EPI) at the provincial level.

Figure 2 shows the administrative structure of the national immunization program in Vietnam. There are presently 696 districts and 11,132 communes in Vietnam.

Figure 2. Administrative structure of the national immunization program in Vietnam



2.1.1. Fee-based immunization

In addition to the public-sector immunization program, Vietnam is experiencing a growing demand for vaccines provided under a fee-for-service model. This system is not strictly a private-sector system, as the majority of these services are currently delivered at public-sector facilities. Immunization is provided for a fee paid by the client and may be administered either in a private-sector or public-sector facility.

In 2009, Optimize conducted an assessment of 44 fee-based immunization facilities, which may represent 10 to 25 percent of the fee-based services in Vietnam. Based on collected data, the 44 facilities administered an estimated 750,000 immunizations in 2009. These were not all childhood vaccines, but by way of comparison, NEPI delivered approximately 17 million doses of vaccine that year. According to this study, there were several reasons why people chose fee-based immunization services instead of receiving free vaccines from EPI providers. These included having access to vaccines that are not provided under the EPI, the convenience of locations or opening hours, and reputation for high-quality facilities.

2.2. The supply chain

Vietnam has a well-established vaccine supply chain. Local manufacturers produce vaccines for DTP, TB (BCG), polio, Japanese encephalitis, cholera, typhoid, measles, tetanus toxoid (TT), and HepB, and deliver them either to the national cold store or directly to the four regional cold stores. Imported vaccines such as pentavalent are received at the national cold store before being transported to regional stores. Vaccines are moved from the regional level to provincial, to district, and finally to communes. Generally, vaccines are only supplied to the commune level for one to three days per month for immunization activities. During the rest of the month, vaccines are not stored at the commune level, except in some remote communes where vaccine refrigerators have been provided.

The structure, practices, and procedures that define Vietnam's vaccine cold chain were developed 30 years ago. Many advances in supply chain technology, developed largely by the commercial sector in recent years, could be used to create a system in Vietnam that can help the government meet the challenges of the future. Due to the rising cost of vaccines and the increased storage capacity required in the cold chain to accommodate new vaccines, managers will be challenged to better forecast vaccine requirements and ensure properly working cooling equipment to protect vaccine stock.

2.3. Baseline assessment

Optimize performed a baseline assessment of Vietnam's immunization supply chain from August 2009 to March 2010. The objective of the assessment was to research the current status of the immunization system in order to identify areas of focus and specific interventions that could demonstrate innovation and potentially be used to strengthen the Vietnamese vaccine supply chain in the future. A report of the assessment methods and findings is available online at:

www.path.org/publications/files/TS_opt_phase1_rpt.pdf

2.4. Challenges and opportunities

Based on the findings of the baseline assessment, Optimize identified opportunities to test innovative technologies and measure the resulting effects on the Vietnamese vaccine supply chain. These are described in Table 2.

Table 2. Opportunities for innovation in the Vietnamese vaccine supply chain

Challenge	Opportunity
Health care workers face a significant burden of work related to the paper-based reporting system; this burden will increase with the introduction of new vaccines.	The reporting burden can be reduced by developing digital reporting systems, enabling health care workers to spend more time on other tasks.

Challenge	Opportunity
Immunization data recorded in the current system are often delayed or incomplete at the higher levels.	The completeness and timeliness of report data can be improved at all levels by adopting digital recordkeeping.
Immunization data recorded in the current system are often incorrect due to estimation and arithmetic errors.	The quality and accuracy of information available can be improved at all levels by adopting digital recordkeeping.
Managers at the national or regional level find it difficult to locate specific vaccines in the supply chain.	Real-time information about vaccines in stock can be increased at all levels by using digital reporting systems.
Delivery of the HepB vaccine within 24 hours of birth is relatively low, resulting in a missed opportunity for the best protection of infants against this pathogen.	On-time delivery of the HepB birth dose can be increased by providing small-volume cool storage containers at CHCs.
Commune and district health centers often have intermittent grid electricity; communes may have trouble securing funds for electricity bills.	The use of passive and solar vaccine cooling technologies that require intermittent or no grid electricity can be explored.
The Vietnamese immunization system relies on various administration, storage, and reporting procedures. However, there is a lack of documented SOPs to ensure that these processes are conducted correctly and consistently.	Efficiency and consistency of performance across the NEPI system can be improved through the development of high-quality SOPs.
High-quality fee-based immunization services are being delivered in both private and public health facilities, but little information about these immunizations is available at the national level.	Reporting structures can be clarified to facilitate information flow from fee-based providers of immunization services. Opportunities also exist to ensure quality through increased monitoring and supervision.

Abbreviations: CHC = commune health center; HepB = hepatitis B; SOP = standard operating procedure.

Following the assessments, and corresponding to the opportunities identified, Optimize and NIHE decided on five major demonstration activities to be conducted under the project:

1. Develop and test a computerized system for tracking vaccine stock and reporting aggregated monthly immunizations data.
2. Develop and test a paper-based and computerized system for aggregated reporting of fee-based immunization services.
3. Test the use of computer and mobile phone technologies to track children due for immunization and to record the immunizations given to them on an individual basis.
4. Use passive-cooling technology to store vaccines in CHCs.
5. Install direct-drive solar refrigerators to store vaccines in district health centers.

In addition to the five demonstrations, Optimize also conducted other activities in Vietnam. These included:

- Providing technical support in the preparation of an EVM assessment in 2012. (The baseline assessment conducted by Optimize in 2009 also included a baseline EVM assessment.)
- Developing new SOPs to standardize best practice procedures.
- Supporting early steps toward the adoption of VVMs by local manufacturers.

2.5. Baseline costing

As part of the baseline assessment conducted in 2009 (described in section 2.3 on page 6), Optimize also analyzed the baseline cost and efficiency associated with the immunization system in Vietnam.

A supply chain model was developed using the Arena® software (Rockwell Automation Inc., Milwaukee, Wisconsin, USA) to provide a visual model of the transport, cold chain, storage, and vaccine modules of the national supply chain and create a platform for simulating changes to the existing vaccine supply chain logistics system and evaluating the associated costs. A costing tool was then created in Microsoft Excel based on the model, and populated by data collected by Optimize and NEPI staff in Vietnam. The supply chain costs by function for both vaccines and dry goods were included in the model as shown in Table 3.

Table 3. Supply chain costs by function

Function	Cost	Function	Cost
Storage	Equipment depreciation	Transportation	Vehicle depreciation
	Energy		Fuel
	Infrastructure		Insurance
	Equipment maintenance		Maintenance
	Labor		Labor

Table 4 shows the estimated cost metrics by level, for both the 2009 EPI schedule before the introduction of the pentavalent vaccine and also for the 2010 schedule after its introduction.

Table 4. Average logistics cost per dose in US$ by tier

Tier	2009 schedule			2010 schedule		
	Cost per dose	Cost per cm^3	% cost*	Cost per dose	Cost per cm^3	% cost*
National	0.003	0.001	1.7	0.002	0.001	0.4

Tier	2009 schedule			2010 schedule		
Regional	0.005	0.001	2.9	0.005	0.002	1.2
Provincial	0.016	0.005	14	0.021	0.005	3.4
District	0.066	0.020	51	0.081	0.019	13
Health center	0.120	0.035	94	0.159	0.036	23
Total cost per dose	**$0.21**			**$0.27**		

* Expressed as a percentage of the total value of vaccines.

The average supply chain cost per dose is lowest at the national, regional, and provincial levels, capturing economies of scale when large numbers of vaccines are stored and transported relative to the fixed capital costs. The average supply chain cost of Vietnam's immunization program was estimated at $0.21 per dose using the 2009 schedule.

Using the 2010 schedule, when pentavalent was introduced, vaccine supply chain logistics costs per dose increased to $0.27, due to a reduction in the number of vaccines in the system (there were fewer doses per fully immunized child and lower wastage rates). This estimate assumes the same labor and transport costs associated with the 2009 schedule, although with fewer vials in the system some costs may have been reduced.

Table 5 shows the estimated costs per fully immunized child. Using the 2009 schedule, the total logistics costs per fully immunized child were $2.92 and accounted for approximately 59 percent of the fully loaded vaccine costs in the 2009 EPI schedule. The fully loaded costs are defined as the sum of the vaccine cost and the logistics costs. With the introduction of pentavalent, the cost per fully immunized child increased to $3.23, but the logistics costs were only 24 percent of the fully loaded vaccine costs due to the relatively higher value of vaccines per child.

Table 5. Costs per fully immunized child

	2009 schedule	2010 schedule
Number of vaccines	14	12
Vaccine costs	$2.00 (41%)	$10.17 (76%)
Logistics costs	$2.92 (59%)	$3.23 (24%)
Fully loaded costs	$4.92	$13.40

A comprehensive report of the baseline costing activity, including methodology and more results, is included in Appendix A.

In this report, we present information on the investment costs for each intervention, while the table on page 82 presents the same information for all interventions together. These costs reflect the full project Optimize costs and may not represent start-up costs or costs of scaling up these technologies if implemented by the national government itself.

In addition to the investment costs, we also compare the intervention cost per dose and other metrics with the baseline system costs for the passive-cooling technology and the solar refrigerator interventions. We estimate the recurrent supply chain costs for these interventions based on information about changes in resource use obtained through interviews with health worker staff at participating facilities.

3. COMPUTERIZED VACCINE TRACKING AND IMMUNIZATION REPORTING

3.1. Goal

Optimize collaborated with NEPI to pilot a computerized logistics management information system (VaxTrak) that helps immunization health workers track vaccine stock as it is received and dispatched throughout the system and that facilitates monthly reporting on immunizations given. The goal was to increase the accuracy and timeliness of vaccine inventory and immunization reports, to reduce the amount of time health care workers spend on reporting duties, and to increase the availability of the data, especially for upper levels at different locations.

Note: The VaxTrak system helps manage vaccine stock data and aggregated immunization information, in contrast to the immunization registry (IR) software (described on page 31), which tracks individual immunization records.

3.2. Rationale

3.2.1. The problem

A major challenge in managing a supply chain is the lack of centralized, timely, and accurate data for effective vaccine stock control and management. Without these data (e.g., doses procured, doses distributed, doses administered, remaining stock, and wastage rates), it is difficult to determine the necessary quantities of vaccines to order or how to manage their distribution. In the absence of reliable information, the supply chain operates on best-guess estimates.

3.2.2. A possible solution

The ability to track and trace vaccines throughout an information-driven supply chain mitigates the risks of understocking (which can lead to stockouts and missed opportunities to vaccinate children) or overstocking (which can lead to wasting vaccines from expiry). Up-to-date vaccine stock information is also very important in the event of a recall of a specific vaccine lot either due to manufacturer notification or an adverse event occurring somewhere in the country. Computers can be used instead of paper registries to track information about vaccine stock throughout the country. Specially designed software would have some advantages over paper records, including:

1. The ability of managers to see the status of every vaccine they are responsible for, regardless of where it is kept.
2. Increased accuracy of recorded information through the use of menus and logical data checks.
3. Automatically generated vaccine use reports based on information stored in the database.

3.3. Implementation

This section describes how VaxTrak was developed and implemented in Vietnam. Table 6 describes the project timeline and major milestones.

Table 6. VaxTrak demonstration timeline

Year	Month	Milestone
2010	July	Preliminary requirements developed, system description completed, and a request for proposals for software developers issued.
	September	Procurement process for software developer completed; company selected.
	December	Proposal agreed to with NEPI; project began.
2011	January	System requirements confirmed. Software development began.
	June	Beta version of software loaded at NEPI for testing.
	August	Updated version of software loaded in Phu Tho province.
	November	Updated version of software rolled out to all three provinces and regions; monitoring period began. Troubleshooting Smart Connect device ended, and that part of the demonstration was abandoned.
2012	January	Review workshop conducted; NEPI makes the decision to expand VaxTrak to an additional 10 provinces, and Optimize supported monitoring in 3 of those. Also will expand to the district level in Phu Tho, and Optimize will monitor 2 of the 13 districts.
	May	Final monitoring visits conducted; data collected.
	June	NEPI provided additional on-the-job training to address user issues identified in final monitoring visits.
	October	End of project results shared in workshop event. Optimize will continue to provide remote technical support as needed until March 2013, as well as support fundraising activities for possible expansion of the system.

Abbreviation: NEPI = National Expanded Programme on Immunization.

When discussing the requirements for this software, it became clear that users wanted a web-based tool to track vaccine stock movements and to record immunizations administered. They wanted data that were aggregated in a central database accessible at the national level as well as other levels, with appropriate access rights defined. ANZ Solution was chosen from among several Hanoi-based software development firms that responded to the request for proposals, and the software was developed over several months.

The VaxTrak tool was introduced in three provinces—Phu Tho (north), Quang Tri (central), and Ben Tre (south)—as well as at the regional and national levels. Once installation and training were completed in October 2011, immunization workers at the participating locations began using VaxTrak for registering vaccine receipts and dispatches, and reporting immunizations administered.

The original concept for the vaccine tracking system included two elements that were subsequently dropped:

- Barcode tracking of vaccines.
- A mobile communications device to track refrigerator temperature while also providing a hub for data input at the point of storage.

These two elements were canceled due to the shortage of time for development and other technical reasons. For the barcodes, since vaccines are not currently labeled with barcodes, adding them to the vaccines destined for project sites would have required significant coordination and labor. While barcodes would have been beneficial, the relative advantage over a menu system, given the limited vaccines in the system, was not worth the effort and cost. For the mobile communications device, we collaborated with a company that had a device in development that turned out not to fit well with the functions required. Also, users indicated they would prefer to use a computer rather than a keypad interface.

After the first three months of implementation, based on feedback from users, NEPI leadership decided to enter into a second phase of the intervention, expanding the number of participating provinces to 13 in total, and adding all 13 districts in Phu Tho province to pilot the software at the district level. Due to human resource limitations, Optimize could not monitor all locations, but of those added in the second phase, the project monitoring was expanded to an additional three provinces and two districts: Can Tho, Hue, and Thanh Hoa provinces; and Tan Son and Phu Tho Town districts in Phu Tho province.

3.4. Results

3.4.1. Accuracy of vaccine stock data

Prior to designing and implementing the VaxTrak software, we developed a monitoring and evaluation framework to identify the indicators we wanted to measure. One thing we wanted to evaluate was accuracy of vaccine and immunization data before and after intervention. In the three original provinces that had the longest experience with VaxTrak, it was possible to collect data from the system database on the quantities of vaccine by lot number and compare them with the actual stock on hand. To be considered a match, the vaccine records had to share the same vaccine name, manufacturer name, lot number, expiry date, and dose quantity. In the baseline survey before implementing VaxTrak, the sets of vaccine in the vaccine ledger matching the actual stock on hand was only 30 of 39 (77 percent accurate) in the three provincial stores. After one year of the VaxTrak intervention, the accuracy of vaccine data improved, with 40 of 40 (100 percent accurate) sets in the software matching the stock on hand. (For this analysis, a set of vaccine is a group of vaccine vials sharing the same manufacturer and lot number.)

However, in the provinces that had a shorter experience with VaxTrak software, users were still learning the processes of using the software, and the electronic data were scarce or not available, making the system's data inaccurate when compared to stock records. There are several reasons for this:

- The software has not been in place long enough for all users to become accustomed to the vaccine management and immunization reporting functions.
- Users did not prioritize the use of the software, as it was considered just a pilot and not compulsory. Data were not often updated and users tended to revert to the more familiar paper-based system.
- During the implementation period, some provincial health workers were asked to use two different immunization software programs in parallel, which created a heavy work burden. Only one of these systems was related to Optimize activities.
- At some locations, users reported that the VaxTrak reporting forms met EPI's requirements but not their financial reporting requirements, so it was not helpful to use VaxTrak.

3.4.2. Reporting process before and after VaxTrak

At the time of the baseline survey, health workers used either a calculator or computer to aggregate data from commune reports. For those using a computer, predesigned Microsoft Excel files allowed health workers to enter data from commune immunization reports, automatically generating results for the entire district. The process of compiling the report on vaccine use was more complicated. Health workers were seen poring over the vaccine register, previous month's reports, and distribution vouchers, trying to reconcile data in order to provide an accurate report.

To create immunization reports with VaxTrak, the reporting district workers input and save data to the "Immunization Report" application of the system. The province can then quickly generate reports that compile all the reporting districts' data. The software includes various reporting formats according to NEPI requirements.

To generate vaccine use reports, the reporting district workers input and save data on the quantities of stock remaining and discarded at the commune level to the "Vaccine Used Report" application of the system. In provinces where the software has not been implemented down to the district level, the provincial-level reporting officer must confirm data with each commune EPI officer before entering the data. The system then uses the commune-level data on stock remaining and discarded, and combines the data with the stock data generated when shipments are dispatched and received in order to automatically generate vaccine use reports.

3.4.3. Time burden of compiling reports

We noted the average time that health workers spent each month making three kinds of report:

- Vaccine use—includes information about vaccine quantities received, used, discarded, and returned.

- Child immunization—includes information about number of children vaccinated by type of vaccine and location.
- Woman immunization—includes information about the number of women vaccinated with tetanus vaccine by location (targeted toward women aged 15 to 35 and pregnant women).

We conducted observations before and after the VaxTrak intervention at five facilities (three provincial and two district). We anticipated that the reporting time would be reduced with use of VaxTrak, since data are automatically aggregated and totals calculated by the software.

Due to time limitations, we could not conduct observations for all three types of report in all facilities. Instead, we observed the child immunization and vaccine reporting at all three provincial facilities, and the child immunization and woman immunization reports at the district level, before and after the intervention. From these data, we found that at the provincial level, the average time health workers spent on the child immunization report changed from 22 minutes before VaxTrak implementation to 16 minutes using VaxTrak. For the vaccine use report, the average time spent changed from 88 minutes to 43 minutes. At the district level, the average time spent on the child immunization reports changed from 39 minutes before implementation to 23 minutes after VaxTrak implementation, and for woman immunization reports, the change was from 10 minutes to 8 minutes.

Phu Tho was the only province where VaxTrak was implemented down to the district level. Once the districts came online, the immunization data were then entered into the VaxTrak system at the district level rather than the provincial level, so the immunization reporting time at the provincial level decreased dramatically since the report was automatically aggregated without any data entry steps. The final observed child immunization report in Phu Tho took only 5 minutes to complete, compared to 22 minutes before VaxTrak implementation. This demonstrates that the ability of the software to save time in the immunization program increases as its use is expanded down to lower levels.

3.5. Acceptability and feasibility

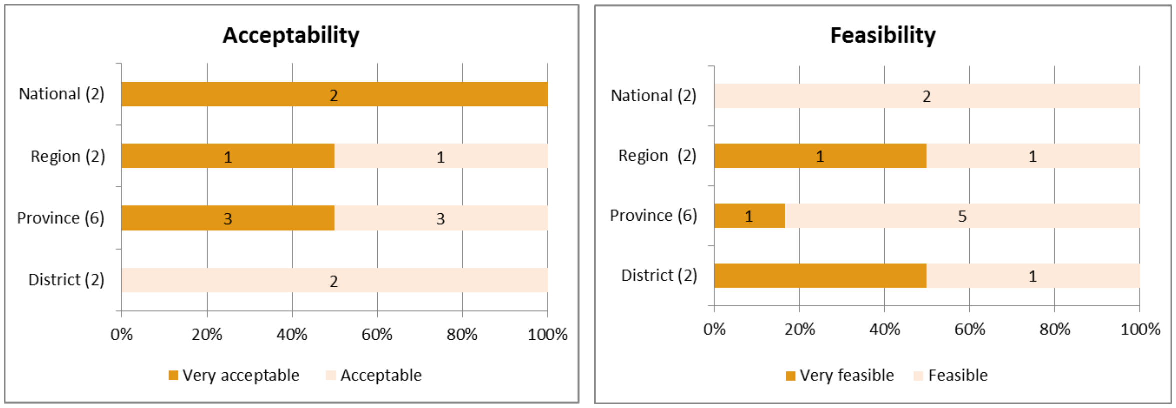
Twelve participants from different levels were included in a study using qualitative research methodology to try to understand user response to the VaxTrak software intervention. All respondents were asked to rate both the acceptability and the feasibility of the software using a five-point scale as shown in Table 7. We explored acceptability and feasibility separately, because although similar, there is an important distinction—an intervention may be acceptable to an individual user in her daily work while at the same time she considers it unfeasible for long-term use or scale-up for a number of reasons.

Table 7. Evaluation scale for acceptability and feasibility questions

Very unacceptable	Unacceptable	Do not know	Acceptable	Very acceptable
1	**2**	**3**	**4**	**5**
Very unfeasible	Unfeasible	Do not know	Feasible	Very feasible

A description of the research method for the study is included as Appendix F. Participant responses are presented in Figure 3. Responses are categorized according to participant level; for each level, the total number of participants is provided in parentheses.

Figure 3. Individual interview responses on acceptability and feasibility of VaxTrak software



3.5.1. Reasons for acceptability and feasibility

Some reasons that health workers gave for responding that the VaxTrak is "acceptable" or "very acceptable" included: the Vietnamese interface is easy to use; because it is online, it is convenient to access the data anywhere and anytime users have Internet access. Users at the regional and national levels liked being able to see the real-time balance of vaccines at all locations under their responsibility, with lot number and expiration date information included. The most commonly cited reason was how user friendly the software was, as a participant stated below:

> *The most important thing is that it is easy to use as many staffs are able to work on it.*
>
> Implementer, province level

Another reoccurring reason for acceptability was the reporting functions the software added. Some respondents mentioned they felt it helps them manage vaccines more accurately and effectively, as described below:

> *Because in this province [we] have long wished for a vaccine management and immunization reporting software. Before the national program also has two tests of software, have been used but not well. The software is good, much better than even the vaccine management, easier to do, easier access and particularly it can be applied to the district level. But the national program's software is only applicable for the provincial and national level. Now, in this province, wishing to have a software from district throughout the province level. Having the software that makes it easy.*
>
> Decision-maker, province level

> *In fact, this software helps us control every stage, from store preservation to distribution planning and monitoring the preservation and distribution in the lower line.*
>
> Designer, national level

Respondents mentioned an increase in timeliness of reporting, and since the software automatically aggregates reports from input data, the time they need to complete reports is reduced. Some also like the graphical presentation of data provided by VaxTrak.

> *This software has more functions in reporting, managing, and storing vaccines. It helps reduce the burden on our staff so one can carry out several tasks.*
>
> Decision-maker, province level

> *The graphs and charts were designed to match the current management demands of the program. Therefore, when we put it into practice, of course it satisfies what we need.*
>
> Designer, national level

Reasons listed by respondents for the feasibility of the VaxTrak software included the fact that the equipment (computers, Internet) was largely available and that it fit well in the situation of use at the various levels, as well as support given by leadership for the use of the software. One respondent listed these reasons for the feasibility of the software:

> *In my facility, the use of software, the network is relatively stable. The second is that its output is also consistent with the needs of this level, moreover, the leaders also support the software that employees see.*
>
> Implementer, regional level

User responses pertaining to acceptability and feasibility of the VaxTrak system often did not reflect the challenges we observed during monitoring, such as those described in "Challenges and lessons learned" on page 20. It could be that the interventions were acceptable and feasible to users in spite of those problems, or users may have been reluctant to report dissatisfaction in the research interviews.

3.5.2. Reasons diminishing acceptability and feasibility

The difficulty of learning the software and increased time to do so was listed as a reason for unacceptability. This was explained by factors of computer literacy, as this respondent explained:

> *This software is new, so sometimes we have troubles using it. My computer skills aren't quite good and it's the same problem among immunization staff in the districts.*
>
> Implementer, province level

In addition, the implementation was just applied at the provincial level (except in Phu Tho province); thus, the provincial staff had increased work burden, as explained by the respondent below:

> *I just think that when the software is deployed in the lower lines, the provincial officials have to do more job as they have to input data from the vaccine reports and immunization reports of the districts too. If we deploy it in the districts, the district officials have to input data from the vaccine reports and immunization reports of the communes too. So, that's a bigger burden for the health workers.*
>
> Designer, national level

Also, Vaxtrak did not meet the requirements of some locations because its printed reporting forms did not match the financial form being used in that location. This happened in cases where the accounting department and planning department used forms that varied from other provinces. One interviewee responded:

> *The authority hasn't approved this vaccine management software or performing store input/output on this software as it relates to taxes and financial problems. They think the software is not effective in accounting.*
>
> Implementer, province level

Finally, this system was a burden to some users at the provincial level because there was another software program in use simultaneously, as this respondent explained:

> *In the early stage, we have to invest more time in the project. Also, since we haven't removed the old one, we'll have more work to do with the new one.*
>
> Implementer, province level

3.5.3. Scale-up considerations

The respondents were asked to consider pros and cons of the software system with regard to scale-up. Factors favoring scale-up that respondents listed included high user acceptability and the availability of computer and Internet connections at most health facilities. Respondents also answered whether they thought the intervention should be continued short term (1 to 5 years), long term (5 to 10 years), or permanently. Their responses are described in Table 8.

Table 8. Responses to the question: How long should the intervention be continued?

Level	Short term	Long term	Permanent
District	1	0	1
Provincial	1	4	1
Regional	0	1	1
National	0	1	1

Respondents stated:

> *If it's just short term, it will be a waste of money and time and not effective. The vaccine management will definitely use the software in the future. Managing it on paper like currently will definitely lead to errors.*
>
> Designer, national level

> *There are many advantages and they have not affected the old activities and procedures. We should implement forever.*
>
> Implementer, province level

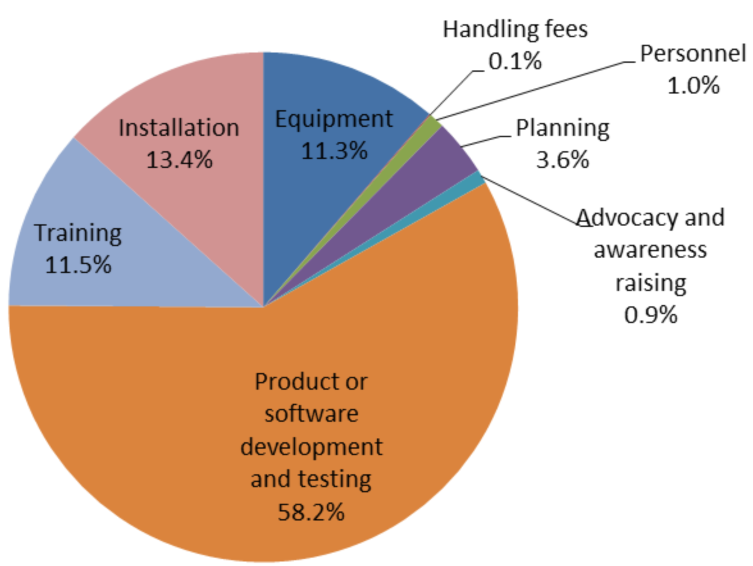
Some of the challenges to scale-up or continuation given included the work required to keep staff trained (in places with high turnover rates), the lack of budget for monitoring and supporting the system in the early stages of implementation, and unstable or unavailable Internet connections in some remote areas. In addition, some respondents listed difficulties with the reporting form functions of the software, described by this respondent:

> *The forms and documents aren't available, so if we want to input information, we'll have to update it in many types. We'll have to select the appropriate information from different sources and add it to the software. Sometimes it's not compatible and doesn't enable changes. That's how we do national management. The software is convenient in data management but it has troubles with the forms in national management.*
>
> Decision-maker, national level

3.6. Cost

The VaxTrak software, implemented at the national store, three regional facilities, 13 provinces, and 13 districts, had a total investment cost of $111,311. Fifty-eight percent of the expenditure was on software development (Figure 4). Other categories with large cost shares were installation, training, and equipment, which accounted for 13 percent, 12 percent, and 11 percent of the expenses, respectively. For the VaxTrak intervention, scaling up the system changes to additional facilities would likely reduce the average costs per facility since the costs associated with product development would be spread over a larger number of participating facilities**.**

Figure 4. Cost profile for VaxTrak intervention



To evaluate the recurrent cost associated with the use of VaxTrak, we collected data on the possible changes in resource use due to the intervention. These resource use questions covered changes in labor time for reporting or estimating vaccine demand compared to the paper-based system, changes in expenditure on stationery, and expenditure for Internet service. Based on information obtained from interviewing staff at selected facilities, there were small and insignificant changes to the use of Internet and stationery because of the intervention. For example, the computers and Internet service were not used solely for the VaxTrak program, so that no observable changes in costs could be documented. The cost of hosting the server at the national level is about $2,000, but this cost is shared between VaxTrak and IR interventions, and when considered per facility is very small. However, the intervention was labor saving—not resulting in the reduction of staff positions, but freeing up health worker time to be able to conduct other activities.

3.7. Challenges and lessons learned

3.7.1. Schedule challenges

Development and introduction of the VaxTrak software took significantly more time than originally planned. There were a number of reasons why delays occurred: it took longer than planned to bring together users to provide input to the system requirements; review of intermediate deliverables from the software developer tended to take longer than planned; and there was more iteration to the program during development than planned. Many small delays contributed to a launch date that was significantly later than originally planned. In the end, this resulted in having less time than expected for the intervention to run in the field sites, which meant that users had less time to learn the software before the end of the project. This had the greatest effect in the three provinces that Optimize monitored in the second wave of implementation—these users did not have enough time to adapt to the software before monitoring was completed. Based on our observations, it took about five months for users to become competent with the software. We recommend that project managers build more time into the schedule to allow for unexpected delays and that they plan a four- to five-month normalization period before monitoring begins in earnest in order to realistically evaluate a software system.

3.7.2. Motivation for users at higher levels

The vaccine tracking function of the VaxTrak software relies on users at the origin of a vaccine shipment to input data about that shipment into the system. Then when the shipment arrives at its destination, a user can search the VaxTrak system, find that shipment's data, and electronically confirm receipt. Because shipments originate at a high level, users at the national and/or regional level must initiate shipments in the VaxTrak system. However, because early interventions took place in only a few provinces, a very small portion of shipments that were being sent by the upper levels needed to be put into VaxTrak, and the storekeepers did not have much motivation to enter the data at all. As a result, when shipments arrived at the provinces, often there were no data in the system corresponding to the shipment—thus, provincial workers could not use the system, and reverted to using only the paper-based system. This problem has not been resolved and still hinders the use of the vaccine tracking function at the provincial level. One solution under consideration is to initiate VaxTrak use at the provincial level and train users in provinces to enter received vaccine into the system rather than accepting shipment data that were input at one of the higher levels.

3.7.3. Managing multiple software interventions

Optimize tested three different applications in Vietnam: the VaxTrak system described in this chapter, the IR described in Chapter 5, and the fee-based immunization reporting system described in Chapter 4. During this time, NEPI was also in the midst of several other software projects, including working with WHO on new vaccine stock management software and with a local vendor on an immunization reporting tool.

Though NEPI welcomed the opportunity to evaluate the advantages and disadvantages of several different tools, the variety did create a challenge for users, especially at higher levels where multiple interventions were taking place. NEPI recommends caution when evaluating different software applications at the same time—clear instructions and communication with users are important for success.

3.8. Next steps

Based on the performance, functionality, and acceptability of the VaxTrak system, NEPI is interested in exploring avenues for scaling up the system to additional provinces following the close of project Optimize. If funding can be identified, additional steps going forward would include:

- Reinstating monitoring and evaluation, especially at the district level, to identify all issues that need to be resolved in the next stage.
- Working with software developers on improvements to the system and ensuring that software design allows for the proposed number of users in the system.
- Designing stages for rollout to new sites and ensuring that adequate training and technical support are available for all users.

4. FEE-BASED IMMUNIZATION REPORTING

4.1. Goal

Optimize collaborated with Vietnam's GDPM to develop and pilot a web-based application that enables users to report fee-based immunization services being provided. The goal was to improve the information at the national level about immunizations being delivered outside the free national immunization program, and to help providers of fee-based immunization services comply with existing national regulations that require reporting of these services to GDPM.

4.2. Rationale

4.2.1. The problem

In recent years, fee-for-service immunization provided in either public- or private-sector facilities (fee-based immunization) has grown rapidly and created more opportunities for the community to access immunization, contributing to further reduction of vaccine-preventable diseases in Vietnam. Fee-based immunization services are relatively new in Vietnam—before 2008, most fee-based immunization services were provided by public health facilities. However, since 2008, after an official Decision of the MOH provided regulation on the administration of vaccines and medical biological products in private-sector health facilities, these services in the private sector have developed and are growing, especially in urban areas.

In a baseline assessment conducted by Optimize in the year prior to this demonstration, findings pointed out that although fee-based immunization services have been provided for some time already, reporting information systems have not yet been fully developed to match that of the EPI network. Further, although the MOH Decision published in 2008 includes guidelines and formats for reporting information, these services have not been fully or regularly reported to the appropriate health officials by all facilities. A report of the baseline assessment findings is available from PATH upon request. Refer to section 1.2 on page 2 for contact details.

4.2.2. A possible solution

The development of specific forms, procedures, and a web-based reporting system for fee-based immunization would help enable the reporting of sufficient, precise, and timely information to the MOH for immunization management. This information could be used by GDPM, provincial health departments, and NEPI for planning, immunization quality monitoring, and service-quality management. The proposed solution would involve three activities:

1. Optimize working with GDPM to develop reporting forms and procedures.
2. Optimize working with GDPM to develop and deliver supportive supervision training for Department of Health staff at the provincial level.
3. Optimize contracting for development of custom software to digitize the forms and provide for web-based reporting by fee-based immunization providers to the MOH.

4.3. Implementation

Table 9 describes the project timeline and major milestones of this demonstration.

Table 9. Fee-based immunization reporting system demonstration timeline

Year	Month	Milestone
2009	Oct. 2009 to March 2010	Optimize assessment of fee-based services in Vietnam.
2011	June	Project agreement signed by PATH and GDPM; fee-based immunization reporting system project starts.
	September	Requirements development completed and initial reporting forms drafted.
	October	Reporting forms finalized.
	November	Software developer selected.
2012	January	First demonstration of web-based reporting system for GDPM.
	March	Software developers changed, as GDPM and PATH were unsatisfied with designs and progression of first developers.
	May	Software installed in Thanh Hoa province for testing.
	June	Testing completed, software installed, and training conducted in all project sites.
	August to September	Acceptability and feasibility data collected.
	October	Review meeting held with GDPM and key provincial leaders and software users.
	November	End of project.

Abbreviation: GDPM = General Department of Preventive Medicine.

Four provinces in Vietnam were chosen to pilot the web application—Can Tho and Ho Chi Minh City in the south, Thua Thien Hue in the central region, and Thanh Hoa in the north. They were chosen to provide a mix of urban city locations and more rural provincial sites. Ho Chi Minh City was included because it has the highest number of private-sector providers in Vietnam. All chosen localities were known to have fee-based immunization services available.

An assessment was conducted to clarify the user requirements and paper-based reporting forms on which to base the web application's reporting features. (Paper forms will be used in provinces where the web application is not introduced.) GDPM staff played a key role and collaborated with NEPI staff and PATH to develop four reporting forms:

- Report on vaccine use.
- Report on immunization activities.

- Report on adverse events following immunization (AEFI).
- Detailed case report for AEFI.

In addition to these reporting forms, the team also designed three booklets for the fee-based immunization providers:

- Vaccine management register booklet.
- Immunization management register booklet.
- AEFI monitoring register booklet.

After the reporting forms and booklets were drafted, an official letter was sent from GDPM to the four project provinces clarifying the procedures for who would report what to whom and when. The health officials from the project sites were brought together to review the contents and format of the reporting forms and provide feedback. Once the forms were finalized, they were shared with the selected developers to be incorporated into the software.

The software was designed to perform the following functions:

- Manage data entry based on the four reporting forms listed above. This module is to be used by the staff at fee-based immunization facilities responsible for statistics tracking and/or reporting.
- Manage data entry based on the EPI's existing reporting forms for immunization of children and women. This module is to be used by the EPI officers at district medical centers. The function of this module overlaps with the data-capturing function provided by the VaxTrak software described in Chapter 3, but was included because none of the sites under the VaxTrak project coincided with the sites for the fee-based immunization reporting project, and health officials at the provincial level wanted to be able to compare fee-based immunization with the EPI immunization in this system.
- Aggregate and report data according to the need at each level. At private-sector facilities, there are four reports, corresponding to the list above. However, at higher levels, there are additional reports that present the data in different ways; for example, a report on vaccine use in fee-based immunization services by commercial vaccine name, and a report comparing immunization results between the fee-based and the EPI programs. In addition, the software allows users to export reported data in charts. In all, district and provincial levels have 13 reports available, and regional/national levels have 18 reports.

Once software development was complete, testing was conducted at the Thanh Hoa provincial PMC and at four district medical centers. Optimize and GDPM staff traveled to Thanh Hoa province to install the software and train users on how to use and test the software and record bugs and issues encountered. After several weeks of testing in Thanh Hoa, and after fixing the issues identified by users there, the software was launched in the remaining project sites. At the end of the monitoring period, researchers visited the study sites to collect data related to basic performance and user acceptability.

To reinforce the management relationship between the health authorities in the PMCs at the provincial and district levels and the fee-based providers, the project included a component to reinforce supportive supervision skills for the PMC staff who are responsible for overseeing fee-based immunization services. Optimize and GDPM staff developed a supervision guideline and checklists for EPI officers to use in monitoring fee-based immunization services, and then provided training focused not only on managing the use of the reporting software, but also on other aspects of ensuring safe and high quality immunization services.

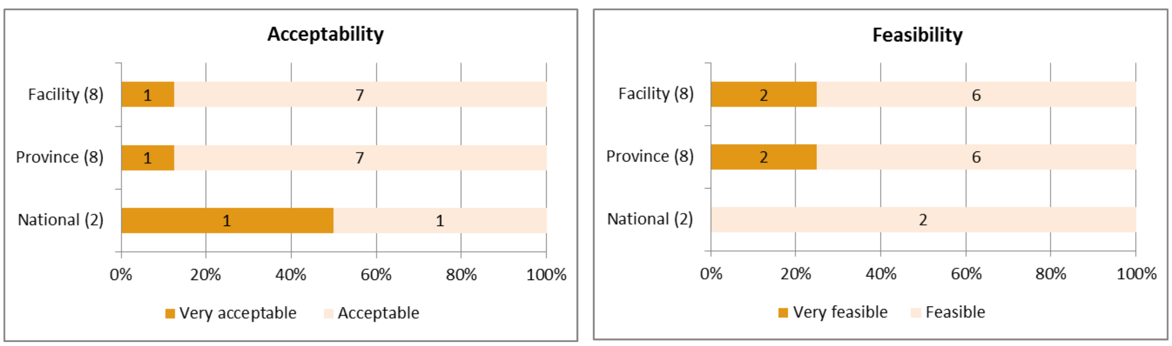
4.4. Acceptability and feasibility

Due to the limited timeline for the fee-based immunization reporting software demonstration, and the dispersed locations of users, Optimize did not formally monitor performance of the software. The acceptability and feasibility research, therefore, comprises the results for this intervention.

In total, 18 interviews with participants were conducted regarding the acceptability and feasibility of the fee-based immunization reporting software. (The evaluation scale for acceptability and feasibility questions is included on page 15.) Overall, the response to the intervention was positive, with the majority of respondents choosing that the intervention was "acceptable" and "feasible" (Figure 5). Responses are categorized according to participant level; for each level, the total number of participants is provided in parentheses.

Data quality, secure data storage, and reporting improvement were the most cited reasons for the acceptability of the fee-based immunization reporting software. Other reasons included reported decrease in workload and that the software was user friendly.

Figure 5. Acceptability and feasibility results



4.4.1. Reasons for acceptability and feasibility

One of the reported reasons for acceptability was the improvement in data quality, including the secure data storage and the availability of these data. One respondent discussed the advantages of the software in the ability to make available data used for management decisions, including accurate immunization rates:

> *I think it has many advantages. It helps managers from fee-based facility up to higher levels to know and manage better. When they're informed, they will have [a] plan, they can estimate vaccine consumption rate and distribute it to the district.*
>
> Decision-maker, province level

Users thought the software has a friendly and easy-to-use interface, and does not require a high level of computer skills. In particular, the software was viewed as helping users to access accurate data wherever they have Internet access.

It's user-friendly and easy to use. You just need to know how to use the computer, and then you can use the software. Nothing complicated.

Designer, national level

It helps managers from fee-based facilities up to higher levels to know and make better management decisions.

Implementer, provincial level

In addition, as this respondent stated, these data filled a knowledge gap that existed about which vaccines are most popular among consumers of fee-based immunization:

There are many vaccines such as chickenpox vaccine, pneumococcal vaccine, etc., which can be compared on the software. We can advise parents to use the vaccine against the disease they want to prevent. This software shows the popularity of each vaccine, which helps us see the actual demand for it.

Decision-maker, province level

Another factor of acceptability reported by respondents was reduced workload. This respondent explained how the software contributed to workload:

According to decision 23, we had to make monthly reports on fee-based immunization to the city government. However, we had to put in data on the software designed by the city government. But since the implementation of this online software, we can reduce data input workload which means a huge reduction in the city's workload.

Decision-maker, province level

In terms of reporting, respondents attributed the availability of accurate reports to the effectiveness of the immunization system as a whole. This respondent explained:

Fee-based immunization used to generate income for the center without any report. But after using the software for a few months, I see that it enables me to have a comprehensive view of immunization efficiency on a monthly basis or over the past months, so that I can make plans for fee-based immunization in the area, such as vaccine acquiring and inventory or distribution to other locations. I think the advantage of the software is that it helps reporting and reviewing so that we can make plans for fee-based immunization.

Implementer, province level

Additionally, respondents listed reasons for feasibility of the software, including availability of equipment (computer and Internet) even at the commune level, easy-to-use interface, and support for implementation from higher authorities.

All preventive health care centers and teams have computers to use the software. The service hasn't been implemented in the communes, but in the future it will. But currently 100 percent of the communes have computers and it's the basis for future development.

Implementer, provincial level

It should be highly feasible everywhere. The authority supports it and we have favorable policies, regulations, and related documents.

Designer, national level

4.4.2. Factors diminishing acceptability and feasibility

The most common factors of unacceptability of this software included some difficulties in the functions of inputting data and processing reports. For example, new vaccines and biological products that had been recently granted import license were not appearing in the vaccine menu as the menu was not being updated in a timely manner. Also, the formatting for the Excel printouts was not working well, so users often had to adjust it manually before printing. An example of one specific change request listed by a respondent:

> *However, for example, I'd like the data output on Excel to be improved. The document should be formatted and ready for printing. Now when I save a document, the cells are of different sizes, which need to be formatted for printing to fit the page in order to avoid content not being displayed on the printed version. The software needs to format the document so that we only need to print it out and sign in it.*
>
> Implementer, province level

Other reasons for unacceptability reported by respondents included the lack of computer literacy of staff using the software and the short time this intervention was implemented. One respondent stated:

> *When the project finishes, people may not have totally understood how it works, and we have little chance to explain everything to them, especially those in the district line whose capacity is quite limited. We may have to explain to them over and over and over again, but we never have the chance to do it.*
>
> Implementer/designer, national level

The most commonly cited reason for unfeasibility included the lack of availability of computers and the unreliability or inaccessibility of Internet for the users. This included many people sharing computers, which could result in the loss of data.

> *The only problem is equipment. I'm afraid we don't have computers and the Internet to use.*
>
> Implementer, facility level

4.4.3. Scale-up considerations

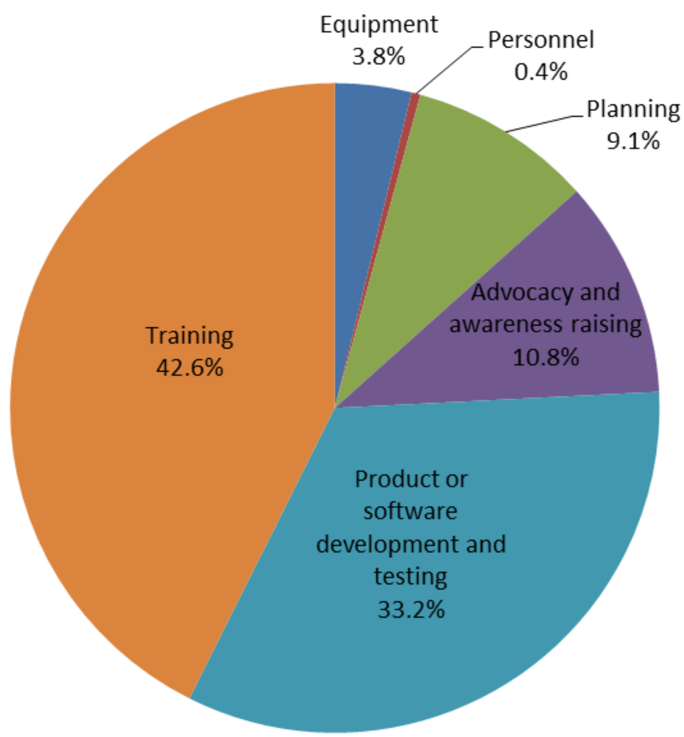
Respondents cited various reasons why the software should be continued and for how long. Overall, the results were mixed as to whether to continue for 1 to 5 years, 5 to 10 years, or permanently. Included in the reasons for a short-term continuation were the reporting challenges explained in section 4.4.2 and the necessary updates that software requires, as well as having a longer trial time in order to test the effectiveness of the software. One respondent explained the reasons for a shorter continuation period:

> *Initially, we should implement it for 1-5 years. After that, we review the actual implementation and make adjustment accordingly. This software may be suitable now but in 5 years' time, it might not. So, we need to improve it for better management. I find 1-5 year period suitable. After that, we'll review it, make use of its strengths and improve its weaknesses, make adjustment to it.*
>
> Decision-maker, province level

4.5. Cost

The total financial investment cost for the fee-based immunization reporting system was approximately $54,000. Figure 6 shows the cost breakdown. The largest share of the total cost went to training, followed by software development and testing. The software development cost is a fixed cost and will be spread among a larger number of facilities if more provinces adopt the immunization reporting system in the future. Recurrent costs would include small fees for Internet service, but as the Internet access at fee-based immunization facilities would not be dedicated for use by this system, the cost would be distributed across multiple applications and programs. Training would be a significant ongoing cost for the provincial health department or PMC in order to maintain good reporting compliance of fee-based immunization providers.

Figure 6. Cost profile for financing fee-based immunization reporting



4.6. Challenges and lessons learned

4.6.1. Schedule challenges

Similar to the VaxTrak software (described on page 11), the software development took longer than originally planned, resulting in less time for monitoring and support to users by the project team and for users to learn the system. One of the causes for delay in the case of the fee-based immunization reporting system was a decision by Optimize and GDPM to change software developer mid-way through the project. GDPM was not satisfied with the early software demonstrations, and another developer was identified that exhibited a better understanding of what GDPM leaders wanted, and more flexibility to create it. This significant mid-course change in the project was costly in terms of both time and financial resources, but we believe that it was necessary in order to reach a satisfactory outcome for the project within the time frame allowed.

4.6.2. Lack of specific reporting regulations and practice

Although the MOH Decision on fee-based immunization (discussed in "Rationale" on page 22) includes the requirement for reporting, there is no specific regulation within the MOH for exactly what should be reported by fee-based immunization providers, nor any specified mechanism for doing so. This resulted in several challenges for the project. First was the need to develop new reporting forms without models from which to build. The second was the lack of a consistent understanding of terms and metrics used in the reporting forms, due to lack of familiarity of practitioners with the types of information that the MOH wants to track. The third challenge was that because fee-based providers were not reporting aggregated data to health authorities at the beginning of the project, the introduction of the fee-based immunization reporting system added to their work burden.

A condition further complicating use of the fee-based immunization reporting system was a perceived disincentive for providers to report these services, which currently provide income for the health system. It was generally acknowledged by GDPM officials and project participants that providers do not want to report fee-based immunizations, either because they do not want to reveal the income generated, or simply because there is no benefit to them from going to the effort of reporting the services. In this environment, strong regulation and adequate enforcement will be needed to ensure more complete and accurate reporting.

4.6.3. Incomplete training across user groups

The project organized a number of training sessions for users at all levels. However, for various reasons, often the staff who would be responsible for using the fee-based immunization reporting system were missing from the training session. As a result, the project training was incomplete, and some users never received proper training.

4.6.4. Incomplete vaccine lists

The vaccines loaded into the system were based on the list of vaccines officially registered by the Vietnam Drug Administration. However, over the course of the demonstration, there were some new vaccines circulating in some project sites that had just received import license and had not been loaded into the system. This was frustrating for users, who could not find in the system all the vaccines they needed to report. This situation points to the need to develop an updating function within the MOH so that new vaccines registered by the Drug Administration are communicated to GDPM so that they can be made available within the reporting system in a timely manner.

4.6.5. No connection between fee-based and EPI immunization data

Optimize had hoped that in the course of the project, we would be able to link the database that contains information about fee-based immunization with the database from the VaxTrak system with information about the EPI immunizations. At the national level, this would provide a clearer picture of immunization throughout the country. Unfortunately, there was not enough time to reach this goal under the Optimize project term, so it remains as something for the MOH to take forward if and when they expand the use of both of these software systems.

4.7. Next steps

The fee-based immunization reporting software showed that data associated with these immunizations could be collected and reported through the use of a centralized database with web interface. This work also contributed to the development of standard reporting forms and provided some training for supportive supervision of fee-based immunization providers by public health officials. As described in “Challenges and lessons learned” on page 28, there were a number of challenges faced in the implementation of the project, some of which will require work on the part of GDPM and department of health officials to resolve. The leadership at GDPM have followed this project closely throughout all activities, and they will take into consideration the benefits and challenges of moving forward with further implementation of this system. They intend to ask the MOH to consider requiring the use of the fee-based reporting system as a criterion for licensing a fee-based facility. GDPM is also currently seeking funding in order to scale up the system.

5. DIGITAL IMMUNIZATION REGISTRY

5.1. Goal

Optimize collaborated with NEPI to demonstrate the benefits of using computer and mobile phone technology to record IR data, tracking individual children due for immunization and recording the vaccinations they have received. The goal was to evaluate how a digital registry might improve the ability to track children due for vaccination and how it might shorten the time required for recording and reporting immunizations compared to a paper-based registry. This system differs from the VaxTrak system described in Chapter 3 in that the IR system manages data about individual children, while the VaxTrak system manages data about vaccines and about immunizations aggregated at a facility level.

5.2. Rationale

5.2.1. The problem

Currently, a detailed paper-based system is used in every CHC in Vietnam to track children due for immunization and record the vaccinations they have received. This system involves making a list of children due and vaccines needed every month before immunization day and adding up the number of vaccines of each type administered for monthly reporting to the district. Searching through the registry for this information on a monthly basis takes significant time and requires copying information and making calculations by hand, which is subject to error.

5.2.2. A possible solution

Meanwhile, Vietnam has developed a strong mobile phone and data network, reaching almost every location in the country, and mobile phone penetration is very high within the population. In addition, more and more CHCs are going online, and have personal computers and Internet connections that allow them to use web-based applications.

Optimize and NEPI saw an opportunity to leverage the existing digital infrastructure in order to try managing immunization data in an electronic form. A custom software program, developed locally, could take advantage of the power of automatic aggregation and calculation functions to ease some of the reporting burden of health workers, while also engaging caregivers through short message service (SMS) messaging to possibly help increase on-time immunization in the community. This digital IR system was therefore chosen as one of the technologies to demonstrate under project Optimize in Vietnam.

5.3. Implementation

This section describes how the IR was developed and then implemented in Vietnam. Table 10 describes the project timeline and major milestones.

Table 10. Digital immunization registry system demonstration timeline

Year	Month	Milestone
2010	December	Proposal agreed with NEPI; project began.
2011	May	Preliminary requirements developed, system description completed, and a request for proposals for software developers issued.
	June	Procurement process for software developer completed, company selected, software development began.
	September	Architecture, technical specifications, and requirements documented by developer and under review by Optimize.
	November	Software developers migrated from OpenXData platform to their own open-source alternative.
	December	Prerelease testing of software.
2012	January	Software launched in Mo Cay Nam district; training conducted.
	February	First immunization session conducted using the software; Optimize staff on hand to support and observe. Process revised in consultation with health workers.
	March	Second immunization session conducted; system works more smoothly using the software. Some additional issues identified and resolved.
	May	Final monitoring visits conducted and data collected.
	October	End of project results shared in workshop event. Optimize will continue to provide remote technical support as needed through March 2013.

Abbreviation: NEPI = National Expanded Programme on Immunization.

The digital IR pilot study took place in one district and its communes. Mo Cay Nam district in the southern project province of Ben Tre was selected by NEPI. There are 17 communes in Mo Cay Nam district, located in the Mekong Delta area south of Ho Chi Minh City. The software requirements included the ability to enter individual children's names and information by personal computer or mobile phone, to search for children across different commune centers within the district, to generate lists of children due for immunization in a given month, to generate monthly immunization reports in the exact format currently specified by NEPI, and to send reminders to parents by SMS a few days before immunization day.

Custom development of the immunization reporting software was chosen as the best approach to achieve the desired performance requirements and to ensure the best local fit for language and mobile network interface. iBase Company, a local developer specializing in web and mobile applications, was selected through a formal bidding process. In the original scope of work for iBase, it was envisioned that the software would be built upon the platform developed by OpenXdata. This open-source software for data collection was founded by a coalition of partners and is connected to Optimize through management committee members located at the University of Bergen, Norway. However, after several months of development, iBase developers recommended migrating to different frameworks for development, namely Google Web Toolkit and Adobe® Flex®.

In January 2012, Nokia C3 mobile phones were distributed to the commune health workers, and training was conducted to demonstrate how to use the phone- and web-based software. The software was used for immunization tracking and reporting from February through May, and monitoring and support visits were conducted regularly during that period.

5.4. Results

5.4.1. Time burden of immunization tracking and reporting

One of the expected benefits of an IR was a reduction in time needed by health workers to prepare immunization reports. We found that the time spent to enter data after every immunization session during the intervention was similar to the amount of time needed to enter data into the paper-based registry (one to four hours, depending on the size of the commune). However, the time for generating the monthly immunization report was greatly reduced by use of the IR. Health workers reported spending about 30 minutes to prepare the immunization report without the software system, but using IR, it took only one to two minutes.

5.4.2. Advantages of electronic data

In addition to time savings during report generation, there are several advantages of having IR data in an electronic format:

- Lists of children due for immunization in a given month can be quickly generated without needing to page through the IR to manually count.
- Automatically generated SMS reminders to parents can replace the tedious job of creating handwritten appointment forms for each child as practiced in some communes.
- Districts can access the data electronically at any time they have Internet access, so they do not need to wait for the communes to report.
- If a child from another commune in the pilot district appears on immunization day, health workers can look up the child's immunization history and see what vaccines she needs.

5.4.3. On-time delivery of vaccines

To help ensure on-time vaccination, the IR automatically generates an SMS reminder prior to immunization day to parents of all children who are due for vaccination. To evaluate the effect of the SMS reminder on the timely delivery of vaccines, we compared the rate of on-time delivery of BCG and pentavalent (DTP-HepB-*Haemophilus influenzae* type b) vaccine before and after the IR intervention. Table 11 shows the results of this comparison. The on-time vaccination rates for all the doses show an increase. The change for BCG vaccine is less pronounced but still significant, as it is a commonly postponed vaccination in Vietnam—parents are often reluctant to bring their child to the health center before he or she reaches one month of age; and babies may not be in their home commune, as new mothers and newborns often go to live with the maternal grandmother for the first one or two months after birth. These data indicate that the SMS component of the IR may be helping more children receive their vaccines on time. One anticipated challenge in ongoing use of the IR would include the work required to keep parents' phone numbers updated in the system.

Table 11. On-time delivery of BCG and pentavalent vaccine

Vaccine dose (Due date for vaccination)	Rate of on-time delivery			
	Before intervention (1/6/2009 to 30/5/2010)		After intervention (1/1/2012 to 31/8/2012)	
	N	%	N	%
BCG (within 30 days of birth)	1,048	44	806	49
Pentavalent dose #1 (between 60 and 89 days of birth)	1,252	54	880	75
Pentavalent dose #2 (29 to 30 days after previous dose)	1,316	61	719	86
Pentavalent dose #3 (29 to 30 days after previous dose)	1,178	58	458	87

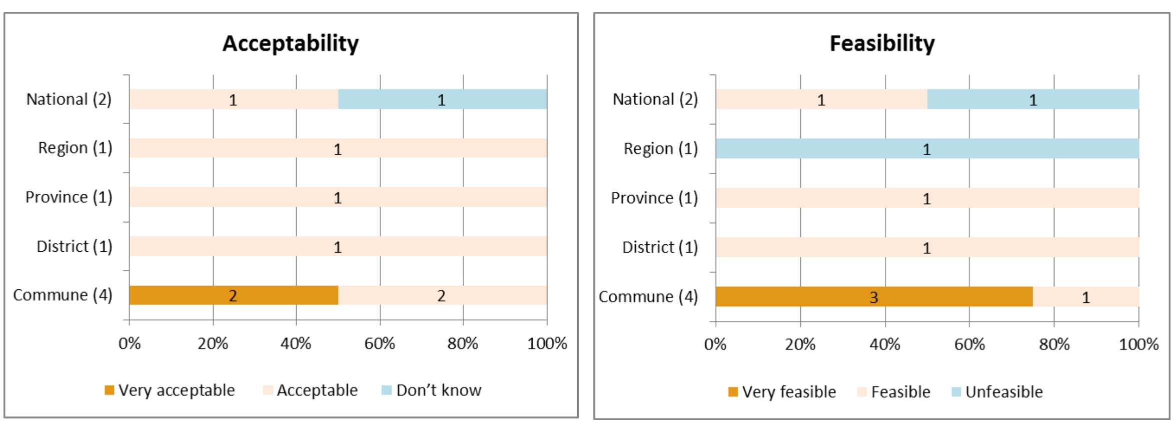
p value < 0.05, all results.

Abbreviation: BCG = bacillus Calmette-Guérin.

5.5. Acceptability and feasibility

Respondents from the national level to the commune level shared their perceptions regarding the acceptability and feasibility of the IR software. Views and opinions varied. Some respondents found the system very acceptable and feasible, some found it unfeasible, and one respondent was uncertain about the acceptability. Figure 7 shows interviewee responses. (Refer to Table 7 on page 15 for the evaluation scale used.)

Figure 7. Individual interview responses regarding IR system acceptability and feasibility



5.5.1. Reasons for acceptability and feasibility

Table 12 lists the factors that users cited as contributing to their perception of acceptability and feasibility of the IR.

Table 12. Factors cited by users as contributing to their perception of acceptability and feasibility of the IR system

Factors that contribute to acceptability	**Factors that diminish acceptability**
• Easy to use, user-friendly interface. • Convenience and flexibility of web-based application—health workers can access the data anytime and anywhere they have Internet access. • Helps health workers track and manage every child's immunization events. • SMS reminders to parents increase the rate of on-time immunization. • Data are more accurate than in the paper-based system. • Increases timeliness of report and reduces time spent generating the report.	• Small font and keyboard size in mobile interface make it challenging for older health workers. • Internet is unstable in some communes.
Factors that contribute to feasibility	**Factors that diminish feasibility**
• Software is compatible with most commune health workers' IT skills. • Availability of computer and Internet connection at commune centers. • Mobile phone fee is reasonably priced. • More than 90 percent of the population has mobile phones, so SMS reminders to parents are effective in most cases.	• CHCs have no income and national immunization budget is limited, so the cost of scaling up the equipment would require donor support. • Health workers at CHCs do not have sufficient experience with using computers.

Abbreviations: CHC = commune health centers IT = information technology; SMS = short-message service.

Out of these, the most reported reason the intervention was acceptable was that it was user friendly and convenient to use, as this respondent stated:

> *Based on what we have already implemented, I think, the software is "Acceptable" because at the level of commune, the users of the software themselves—the commune-line health workers—are able to use and find it useful.*
>
> Designer, national level

As a factor of convenience, some respondents also alluded to the reduction in workload due to the software implementation:

> *I mean if we do the job with this computer, it takes 1 hour to finish. But if we do it on paper, it may take up to a whole day, and then we may have to review it to avoid errors. With this machine, after the input is complete, we can just click and it shows everything.*
>
> Implementer, commune level

Also cited as a reason for acceptability was an increase in the immunization program quality by reaching more children, as illustrated by these respondents' reasons:

> *I think the most important advantage of the software is increasing timeliness of reports and reducing errors. Sending text messages to remind families of their children's immunization is also important because if they forget, they won't come…It helps people remember the date to take their child to the immunization site. That's the most important.*
>
> Implementer, commune level

> *What I appreciate the most in this system is that few children are missed, vaccinations are given sufficiently and timely to each child. The parents also care more about taking care of their child and work closely with health workers to take care of their child.*
>
> Implementer, commune level

5.5.2. Factors diminishing acceptability and feasibility

Most of the factors listed as reasons for unacceptability/unfeasibility included the difficulty of learning and using the software. One respondent, when prompted about the problems of the software, responded that the staff still had not mastered the software:

> *From what I extracted for the reports, it's the staffs' lack of skills proficiency*
>
> Implementer, district level

The other commonly cited factors for unfeasibility were technical issues encountered while implementing this intervention, and issues with the equipment or infrastructure in place to ensure it is properly working (computers, stable Internet connection). One respondent listed problems encountered:

> *Generally this system is good but there are still some problems. For example, the text in my mobile phone is too small, and the keyboard is also too small so sometimes it's hard to type in. Another thing is that we aren't used to it yet so work is slow. About the text messages, sometimes they're not delivered. And sometimes people get the message but they don't read it.*
>
> Implementer, commune level

5.5.3. Scale-up considerations

Respondents gave mixed responses when asked if the intervention should be continued and for how long. Some respondents reported that the software should be implemented for a few more years as a trial phase and then implemented permanently if the results showed that it was successful. As this respondent explained:

I think, if possible, we'll do it step by step. For example, as we have just implemented in a district so it will be expanded in the designated province. Then after a short while, five years for example, if having good result it will continue to be expanded, and if possible, permanent or forever use.

Designer, national level

Others thought that the software should be continued permanently. This respondent explained that if users find the software acceptable, then it should be used for a long time and updated regularly in order to make best use of it:

The software was made to be used. I think it should continue to be used in the central line. But it depends on the users, whether they'll accept it and whether they'll still think it's highly acceptable once they've used it. Another important thing is that we have to monitor and complete it over time. The immunization tools and machines need maintenance and so this software needs also. It's important to take care of it…If the software is adjusted and upgraded, it can be used forever. We shouldn't use it for a short time and switch to another. If we take care of it, upgrade and complete it, then it can be used for a long time and that's very beneficial.

Decision-maker, national level

Another respondent expressed hesitation as to the intervention's ability to be replicated in other locations:

Actually this software and the text messages aren't really effective in remote, mountainous areas. It's more suitable with convenient locations. We can use the text messages to remind them. Mobile phones aren't popular in remote areas yet. I think the software can be applied in 1/3 of the locations. It's hard in the other 2/3 (because of the popularity of the mobile phones).

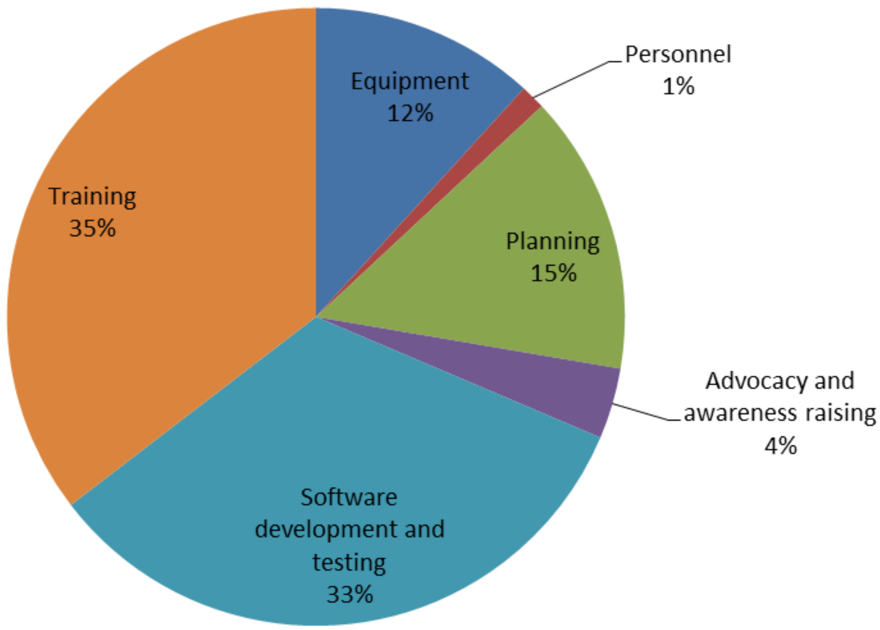
Decision-maker, national level

5.6. Cost

5.6.1. Investment costs

The investment costs for IR were approximately $27,000 in total or approximately $1,500 per facility (for 17 CHCs plus the district). As Figure 8 shows, training accounted for 35 percent of the expenditure and software development accounted for 33 percent. The remaining third was on purchasing equipment, training, and installation.

Figure 8. Cost profile for immunization registry intervention



5.6.2. Recurrent costs

Similar to the VaxTrak recurrent cost analysis reported on page 19, we looked at possible changes in resource use due to the intervention, including changes in expenditure on stationery and Internet service. Again, for IR, there were small and insignificant changes to the use of Internet and stationery because of the interventions and no observable changes in costs could be documented. However, the intervention was labor saving, not resulting in the reduction of staff positions, but freeing up health worker time to be able to conduct other activities.

5.7. Challenges and lessons learned

5.7.1. Schedule challenges

Similar to the VaxTrak software (described on page 11), early project planning and IR development took longer than originally planned, resulting in less time for monitoring and for users to learn the system. There were only four months of use between product launch and final monitoring visits, but if data collection had taken place after users had more time with the software, the lessons may have been different.

5.7.2. Range of experience with computer and mobile-phone use

Unlike the VaxTrak system described in Chapter 3, the IR was implemented at CHCs, where users had different levels of experience using mobile phones—some had never used the SMS function of their phones, while others were very adept at mobile-based applications. There was a similar range of computer experience. Users for whom the digital equipment was novel had a very steep learning curve and some did not have time within the monitoring period to become comfortable with the technology. Others quickly adapted to the technology, were able to problem-solve within the system, and expressed a strong appreciation for working electronically. Projects working at small health centers with new mobile- or personal computer-based applications should ensure that there is adequate technical support to help users, especially technologically naïve users, overcome their difficulties without becoming frustrated.

5.7.3. Inconsistent requirements across locations

During the IR implementation, Optimize was surprised to find that even within a single district, there was some variation in the way communes reported indicators. Small differences in reporting practice can present challenges to software applications. One example was the way that HepB and BCG birth doses were recorded. Some communes reported the birth doses of all the children in the commune regardless of where the immunization was administered, and others reported only those birth doses that were administered within the CHC. Resolving these types of reporting differences requires that: (1) someone discovers the differences; (2) program leaders communicate a clear direction; and (3) users comply with directions.

5.7.4. Long-term technical support needed

Implementation of software technologies such as the IR requires long-term technical support in order to be sustainable. Since the commune level has not yet used many information technologies, the NEPI structure does not currently provide information technology (IT) support at commune level. Providing more technical support to commune health workers would require significant commitment from the MOH to provide the budget and management guidance needed.

5.8. Next steps

The IR has had some level of success in the Mo Cay Nam district demonstration, especially among users with a medium to high level of comfort with computer and mobile phone technology. This system is quite forward looking, and the Vietnam MOH has recently begun to build a strategy around electronic health information management. Individual registry software similar to what Optimize has demonstrated has applications beyond immunization—it can track women in antenatal care, children in the nutrition program, and patients on long-term care regimens such as TB and HIV treatment. The base application that was developed and the lessons learned could have a direct impact on Vietnam's broader health system in the near future. In the meantime, Ben Tre province plans to adopt the use of the IR web-based program throughout the province, expanding to the other eight districts not included in the Optimize demonstration.

6. PASSIVE COOLING AT COMMUNE HEALTH CENTERS

6.1. Goal

Optimize collaborated with NEPI to evaluate a new passive-cooling technology that can function without electricity. The goal of doing so was to enable vaccine storage at CHCs all month along, instead of only during one to three days per month as is the current practice at most CHCs. More access to vaccines at the CHC might increase immunization rates, particularly the rate of on-time delivery of vaccines scheduled for the first day following birth.

6.2. Rationale

6.2.1. The problem

Given the large number of CHCs in Vietnam (nearly 11,000) and the small population served at each center, it is neither practical nor cost effective to equip every CHC with its own vaccine refrigerator. In addition, sporadic power availability at many health centers would make electric refrigeration difficult in these locations. Using a monthly immunization day system, commune health workers have been able to deliver vaccines to an impressively high percentage of the population while bringing in vaccine stock for only one to three days per month. However, the immunization program is still striving to increase the on-time delivery rate of the first dose of HepB, which must be administered within 24 hours of birth to be most effective in preventing mother-to-child disease transmission.

6.2.2. A possible solution

Nano-Q is a new device from US-based Savsu Technologies that uses state-of-the-art insulation materials and a unique configuration designed to maintain appropriate temperatures for vaccine storage without electricity. Optimize chose Nano-Q because it can provide up to seven days of cooling between recharges at an ambient temperature of 32°C, and recharging can be accomplished with normal ice available for purchase close to the CHCs. As it uses no electricity, Nano-Q has no electric or moving parts, and requires no regular maintenance to keep it running.

Optimize wanted to evaluate whether using a passive-cooling technology like Nano-Q for CHC vaccine storage could enable an increase in coverage of the critical HepB birth dose.

6.3. Implementation

This section describes how the Nano-Q demonstration was implemented in Vietnam. Table 13 describes the project timeline and major milestones.

Table 13. Nano-Q demonstration timeline

Date	Milestone
July 2011	First unit tested at NEPI.
August 2011	Field equipment ordered and delivered.
September 2011	Protocol finalized, equipment installed, and users trained.
October 2011	First monitoring visit. Temperature data reviewed.
November 2011	Report from Phu Tho that temperatures dropping to less than 2°C.
December 2011	Confirmed that temperatures are dropping to less than 2°C in Quang Tri and Phu Tho. NEPI decides to begin storing vaccines in Nano-Q in Ben Tre province only.
February 2012	Second monitoring visit. Demonstration halted in Quang Tri and Phu Tho provinces.
May 2012	Final monitoring visit in Ben Tre province.
October 2012	End of project.

Abbreviation: NEPI = National Expanded Programme on Immunization.

The Nano-Q was piloted in 12 communes in three provinces: Phu Tho (north), Quang Tri (central), and Ben Tre (south) (see Table 14). The criteria used to select the communes included the number of births at the CHC, coverage of HepB birth doses given within 24 hours, and reliability of electricity.

Table 14. Demonstration sites for Nano-Q cold boxes

Province	District	Commune
Phu Tho	Phu Tho Town	V n Lung
		Hà LỪc
	Viet Tri city	Thanh Dinh
		Kim Duc

Province	District	Commune
Quang Tri	Trieu Phong	TriǬu L ng
		TriǬu S¡ n
	Vinh Linh	B¿n Quan
		V)nh Kim
Ben Tre	Thanh Phu	Tan Phong
		Th¡ nh Phong
	Binh Dai	Châu H° ng
		LǛc Thu- n

The demonstration began in September 2011 with the plan to monitor temperatures electronically in the vaccine compartment and in the room where the Nano-Q cold box was kept for at least one month before storing actual vaccines in the boxes. The data collected after one month showed excellent temperature performance of all the Nano-Q boxes. However, in late November, V n Lung commune in Phu Tho province reported that temperatures were falling to less than 2°C. Further investigation showed that several of the Nano-Qs in Phu Tho and Quang Tri provinces were exhibiting temperatures of less than 2°C. For that reason, vaccine storage was never authorized for Phu Tho and Quang Tri provinces, and the demonstration was stopped early. Vaccines were stored in Nano-Q boxes in Ben Tre province from December 2011.

NEPI and PATH staff visited the communes approximately every three months to download data from the temperature recorders. In addition, after the stabilization period and at the end of the project, the research team collected information about acceptability of the device from the commune health workers.

6.4. Results

6.4.1. Temperature performance of Nano-Q

The temperature performance of the Nano-Q was good, generally maintaining temperatures between 2°C and 8°C, as recommended by vaccine manufacturers. This was due not only to the performance of the Nano-Q but also to user compliance. Users were required to monitor the temperature daily and change the ice in the device when the thermometer indicated rising temperature in the vaccine compartment.

Table 15 displays an analysis of the temperatures outside of the 2°C to 8°C range that the data loggers recorded. The amount of out-of-range time is shown in hours and as a percentage of total logged time. There are several points to note from this analysis. First is the near-absence of freezing temperatures. The one instance of freezing in V n Lung commune may have been due to a worker accidentally leaving the temperature probe outside the vaccine compartment after changing the ice. The second point to note is the considerably greater number of instances of temperatures less than 2°C in Phu Tho and Quang Tri provinces compared to Ben Tre province. This is due to the lower ambient temperatures in the central and northern regions of Vietnam during the winter months and is discussed later. However, even though it was quite common in Phu Tho and Quang Tri for the vaccine compartment temperature to drop to less than 2°C, it generally did not drop far below this mark, as indicated by the small number of hours with a recorded temperature of less than 1°C.

Looking at the number of hours with recorded temperatures greater than 8°C, Table 15 shows that most communes had only a day or two of cumulative time in this range, out of a total of eight months of monitoring in Ben Tre and five months of monitoring in each of the other provinces. Several exceptions merit discussion. In Kim Duc commune, Phu Tho province, the logger recorded 455 hours of temperatures greater than 8°C. About 340 hours of this took place over a two-week period during which no ice was maintained in the device. This was shortly before the discontinuation of the study in Phu Tho and Quang Tri—health staff may have been confused about the study instructions. In Vinh Kim commune in Quang Tri province, many of the 270 hours recorded of temperatures greater than 8°C took place during two periods when the ice was apparently not replaced—an 11-day stretch in January 2012, which may have been deliberate; and a three-day period at the end of March, which may have been a compliance issue. Appendix D shows temperature traces for all communes over the full monitoring period.

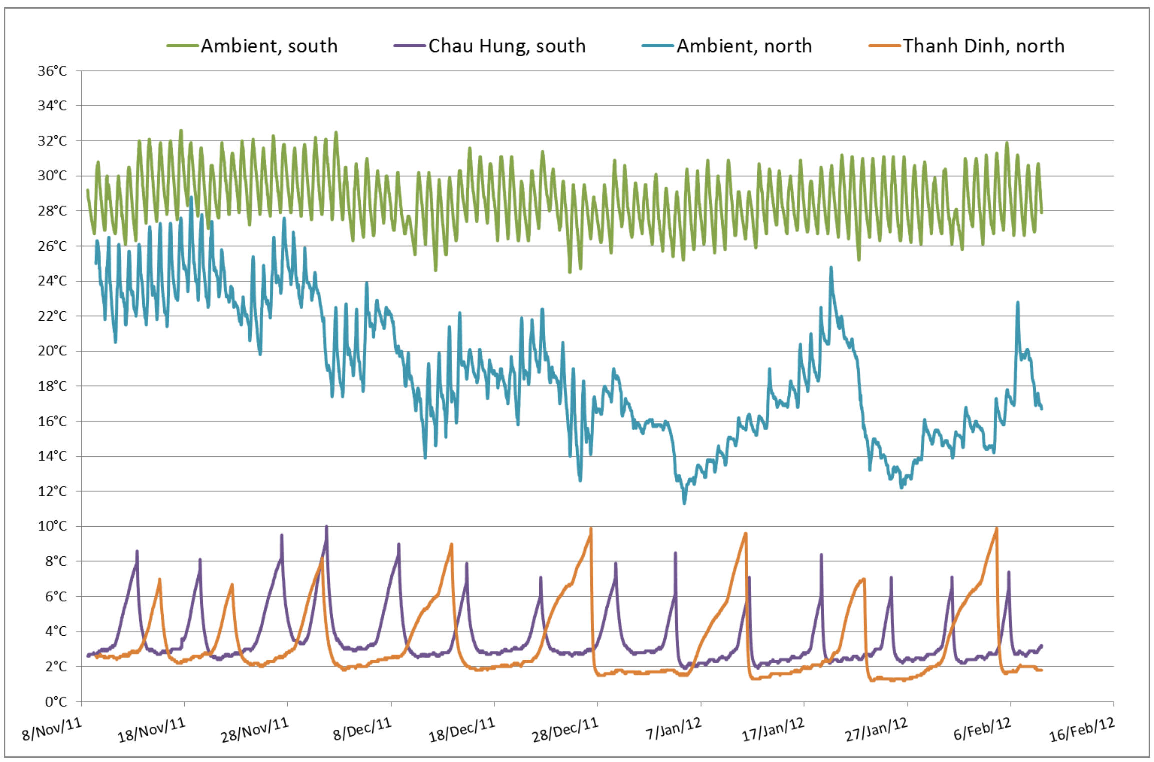
Table 15. Nano-Q vaccine compartment temperatures out of the 2°C to 8°C range*

	Commune	Time >8°C		Time <2°C		Time <1°C		Time <0°C	
		# of hours	% of total	# of hours	% of total	# of hours	% of total	# of hours	% of total
Phu Tho	V n Lung	50.0	1.5	955.3	28.8	31.7	1.0	11.3	0.3
	Hà LÙc	12.3	0.4	772.7	23.0	0	0	0	0
	Thanh Dinh	82.0	2.4	677.3	20.2	0	0	0	0
	Kim Duc	455.0	13.7	81.0	2.4	0	0	0	0
Ben Tre	LÙc Thu-n	22.7	0.41	0	0	0	0	0	0
	Châu H°ng	30.0	0.54	5.3	0.10	0	0	0	0
	Th¡nh Phong	118.7	2.15	27.0	0.49	3.0	0.05	0	0
	Tan Phong	52.7	1.05	0	0	0	0	0	0
Quang Tri	TriÇu L ng	0.3	0.0	286.2	9.4	5.0	0.2	0	0
	TriÇu S¡n	2.3	0.1	275.0	9.1	0	0	0	0
	Vinh Kim	270.3	9.1	252.0	8.4	0	0	0	0
	B¿n Quan	7.0	0.2	384.7	12.8	0	0	0	0

* Duration of study varied between provinces. Phu Tho and Quang Tri: 5 months; Ben Tre: 8 months.

Starting in late November, demonstration CHCs in Phu Tho province in the north and Quang Tri province in the central region noted that vaccine compartment temperatures were dropping to less than 2°C. This was due to the low ambient temperatures that occur in the wintertime in these regions. Figure 9 shows a comparison between a Nano-Q in Ben Tre province in the south, where average ambient temperatures stay near 30°C all year, and a Nano-Q in Phu Tho province. The periodic rise and fall of temperature in the vaccine container is due to the cycle of ice replacement and gradual melting over six to eight days. This indicates that the period between ice replacements is longer in colder ambient temperature than in warmer temperatures, as expected. It is clear from this chart that as the ambient temperature drops to less than 20°C in Phu Tho, the Nano-Q vaccine compartment begins to exhibit temperatures of less than 2°C. This was unacceptable to NEPI, even though the temperature did not approach freezing, remaining well greater than 1°C, and the intervention was discontinued in Phu Tho and Quang Tri because of this performance.

Figure 9. Comparison of the behavior of the Nano-Q in cool and warm ambient conditions



6.4.2. On-time delivery of hepatitis B birth dose

Looking at the on-time immunization rates for HepB birth dose during the use of Nano-Q, there is a large increase in most communes compared to the baseline. However, the baseline data were collected for the year of 2009, and looking at 2011 data prior to the start of the intervention, there is also a significant increase compared to the baseline, indicating that the rate of on-time delivery of HepB birth dose may have been rising for reasons external to the Optimize intervention. Also, the national rate for this indicator is similarly increasing. Other factors that confound the analysis of this indicator include:

- The number of births occurring at most of the CHCs was small and decreased as more mothers chose to deliver at district hospitals.
- Some CHCs were already making an effort to collect HepB vaccine for birth doses from the district before the intervention. Consequently, though Nano-Q may have made it easier for health workers, it would not result in an increase in the on-time rate.
- All CHCs have small domestic refrigerators that are sometimes used for storing HepB vaccine for birth doses. In this case, again the presence of the Nano-Q would not increase the HepB birth-dose rate, but the quality of storage would improve, as domestic refrigerators often operate with frequent periods of temperatures below freezing.

So while it is good news that the on-time rate for this important vaccine dose is increasing, it is probably not realistic to attribute the change to the use of Nano-Q.

6.5. Acceptability and feasibility

In May 2012, the Optimize team conducted acceptability and feasibility research. (The evaluation scale for acceptability and feasibility questions is included on page 15.)

The nine respondents at the commune, district, and provincial levels interviewed about the Nano-Q cold box reported that they found it either "acceptable" (6) or "very acceptable" (3) and "feasible" (7) or "very feasible" (2). No respondents reported the Nano-Q was "unacceptable," "very unacceptable," "unfeasible," or "very unfeasible."

6.5.1. Reasons for acceptability and feasibility

Health workers listed several positive aspects of the technology, including the ability of the Nano-Q to maintain safe temperatures and prevent freezing and the ease of managing and monitoring. As this respondent stated:

> *This cold box stores vaccines well, at temperatures from 2 to 8 degrees and no fear of freezing.*
>
> Implementer, district level

Users also appreciated the fact that it does not require electricity. Several health workers expressed satisfaction with having a safe place to keep vaccines at the CHC between immunization sessions, and at least one worker mentioned that the Nano-Q creates extra capacity in the cold chain. Some mentioned that it is a good size for CHCs, while others expressed concern that it is not big enough for larger communes or campaigns. In centers that provide frequent labor and delivery services, workers highly valued the ability to keep HepB vaccine on hand in the CHC. Most interviewees agreed that the Nano-Q is a good fit for communes that have no specialized vaccine refrigerator and where electricity is poor, distances are far, and travel is difficult, as reflected in these comments:

> *It is easy to use, very convenient, small and moveable. You can move from this place to another place much more easily than an electric fridge, and is still stable.*
>
> Implementer, commune level

> *The storage duration is longer than others. Other types of storage box can only keep vaccine for 2-3 days, but this one can keep for 1 week. It's a big plus, especially for mountainous areas.*
>
> Implementer, district level

6.5.2. Factors diminishing acceptability and feasibility

When interviewees were asked what aspects of the Nano-Q were unacceptable and unfeasible, many reasons were mentioned, but most had to do with the supply and provisions of ice for the cold box, with some respondents mentioning the cost of the box itself as making it unfeasible. Their concerns included the extra work required to change the ice, and one user mentioned the expense of extra petrol used to fetch ice. In Phu Tho and Quang Tri provinces, it was noted that the ice supply is limited in winter when there is lower demand. In summer it is easily available, but higher demand makes it more expensive. Respondents explained their challenges with this issue:

> *After one year of trial run, we have closely monitored the storage operation at commune line and I have seen that the cool box has a small size and is easy to use; but the shortcoming is that in winter we people don't produce much ice as in summer, and there might be less ice for storage. Moreover, in winter, the monitored temperature is lower than the regulation temperature. If we can fix this problem, the cool box will certainly be more effective.*
>
> Implementer, district level
>
> Q: *Do you find something unfeasible on this cold box?*
>
> A: *First is the purchase of ice in winter. Worrying about winter temperatures, it will be difficult to maintain, the temperature will be unstable.*
>
> Implementer, district level
>
> *I look forward to have a cold box which only needs to change the ice 3 times per month, (every 10 days); with this box I change ice many times.*
>
> Implementer, commune level

As this respondent stated, there are still some unresolved anxieties about the performance and ongoing provision of ice for the cold box:

> *Buying ice in winter can be difficult. During cold weather ice is not produced very much, so we may have to travel a long way to buy 10 kilograms of ice, but how long will it last? Will it be able to ensure temperature between 2 to 8 degrees C until we can find ice again? We are afraid that it cannot.*
>
> Implementer, district level

6.5.3. Scale-up considerations

Regarding continuing the intervention, most responded that it should be continued only on a short-term basis, and reevaluated, because of the current challenges. Even so, respondents noticed the value of the intervention on a long-term or permanent basis once it was improved:

From the beginning, this program is said to be practical, it is for children and they are the target that benefit most from this program. For those children at medical aid stations being equipped with cool box, they will get hepatitis B vaccine immunized sooner. So I think this program is for the interest of children and of society in general.

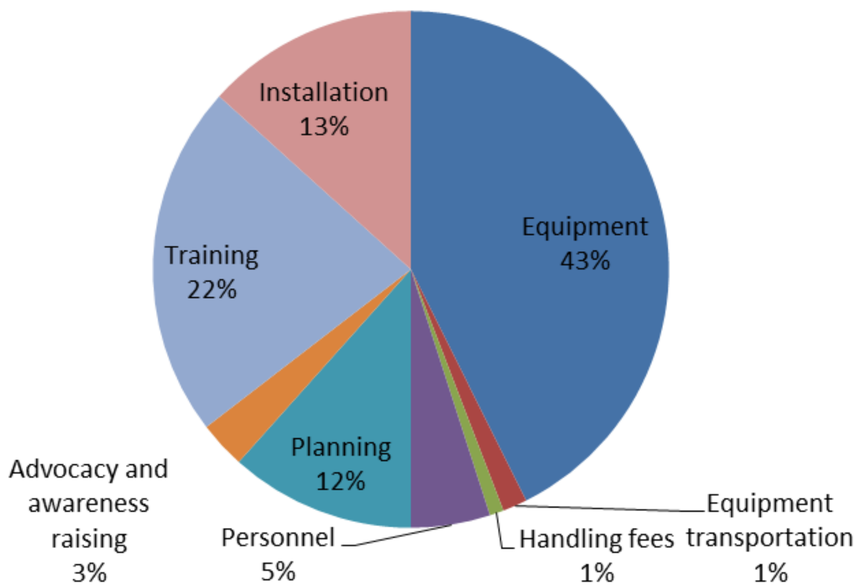
Implementer, district level

6.6. Cost

6.6.1. Investment costs

The investment cost for the Nano-Q demonstration was approximately $34,000 in total or $2,865 per facility. As shown in Figure 10, the largest share of the total cost was spent on equipment (43 percent), followed by training (22 percent), installation (13 percent), and planning (12 percent).

Figure 10. Investment cost profile for passive cold box intervention



6.6.2. Recurrent costs

We also modeled the recurrent costs of using the Nano-Q at the CHCs. Even though the use of the passive cold boxes was suspended at some of the CHCs, we estimated the recurrent costs assuming continued use of the equipment at all sites. Table 16 shows the estimated recurrent annual costs by input type. The introduction of the passive cold boxes at the CHCs increased the total cost from $237 to $267, which resulted in an increase to the cost per dose of $0.06. This increase was mainly due to an increase in the depreciation costs for cold chain since three out of the 12 CHCs in the sample did not have any refrigerators at baseline, and six were using domestic refrigerators, which have a lower replacement price than the passive cold boxes. The energy costs per month for facilities using electric refrigerators were similar to the cost of ice to replenish the Nano-Qs (approximately $5 per month). However, a few of the CHCs were using gas refrigerators and as the cost of gas per month was approximately $20, the Nano-Qs resulted in a large savings on energy for those facilities. Labor and transport costs increased slightly because of the weekly trips to purchase ice.

Table 16. Average recurrent annual costs at the health center by input type for the passive cold box intervention

	Baseline (US$)	With passive cold boxes (US$)
Labor and per diems	61	81
Depreciation of vehicles	0	0
Depreciation of cold chain equipment	86	102
Vehicle fuel costs	22	27
Energy costs for cold chain	69	58
Total costs	**237**	**267**
Number of doses	1,428	
Cost per dose delivered at the health center	0.16	0.22

6.7. Challenges and lessons learned

The biggest challenge for the Nano-Q passive vaccine storage boxes was the low ambient temperatures in Phu Tho and Quang Tri provinces and the corresponding drop in vaccine storage temperature to less than 2°C, the lower limit recommended by vaccine manufacturers. After careful analysis of the data, it is noted that the temperature did not drop to much lower than 2°C and the Nano-Q provided good protection against freezing even in low ambient temperatures. After observing the low temperatures starting in November, PATH arranged for a laboratory test of the Nano-Q at Seattle headquarters to see how it would perform when ambient temperature was held at 10°C for an extended period of time. The Nano-Q was acclimatized in the environmental chamber set to 10°C, then loaded with ice, and the temperature in the vaccine compartment was monitored over 25 days as the ice slowly melted. Results showed that the vaccine compartment temperature never fell to less than 1°C. Given these findings and the minor scale of the excursions to less than 2°C in the field, it would be helpful to have advice from WHO about whether the Nano-Q could be used in cooler settings.

6.8. Next steps

The Nano-Q boxes situated in Ben Tre province in the south of Vietnam will continue to be used. NEPI will decide what to do with the boxes in the central and north regions, which were discontinued during the demonstration when temperatures dropped to less than 2°C in the vaccine compartment. There are at least three options for NEPI at this time:

- Reconsider the use of the boxes for year-round storage in the north and central regions.

- Keep the boxes in the north and central regions for use during warm months only.
- Move the boxes from the north and central regions to the southern region and recommission them in appropriate commune locations there.

Large-scale purchase and distribution of additional Nano-Q devices in Vietnam's immunization program in the short term is considered unlikely due to the high capital investment needed.

Optimize would like to encourage Savsu to consider submitting the Nano-Q to WHO for prequalification as soon as the appropriate standards are published, expected later this year. The device has performed well in Vietnam and offers a number of benefits for specific settings in the immunization cold chain.

7. DIRECT-DRIVE SOLAR REFRIGERATORS

7.1. Goal

The goal of this demonstration was to determine whether direct-drive solar technology is a viable option for storing vaccines in different regions of Vietnam, in terms of equipment performance, cost, and available solar energy.

7.2. Rationale

7.2.1. The problem

For years, gas refrigerators have been used for the immunization cold chain in areas with little or no refrigeration. However, kerosene refrigerators are very difficult to maintain in the safe temperature range of 2°C to 8°C, and liquid petroleum gas can be expensive. Both types of gas require careful supply management and are sometimes not available or diverted for other uses. When solar vaccine refrigeration emerged in the early 1980s, it was very expensive, but eliminated energy costs and problems with energy supply. However, the large batteries used to store energy for the night and cloudy days in traditional solar refrigerator systems presented maintenance and cost problems that have inhibited faster growth of this technology in vaccine cold chains.

7.2.2. A possible solution

To address these problems, manufacturers have created a new type of solar refrigerator that eliminates the need for a battery—the direct-drive solar refrigerator. Direct-drive solar refrigerators store energy in the form of ice in the cooling system, which provides the temperature control needed at night and other times of insufficient solar radiation. Given the problems with gas refrigerators and the continued cost reduction of solar panels, direct-drive solar refrigeration is poised to become increasingly important in developing country vaccine cold chains. However, because they fall within a new category of technology, more information is needed about how they perform in the real world. The demonstration project in Vietnam was designed to help learn more about these devices in immunization cold chain settings.

The BLF 100 DC Sure Chill® vaccine refrigerator manufactured by True Energy was selected for use in the demonstration. One of the two refrigerators used for the demonstration was donated by True Energy. Laboratory testing showed that it can successfully maintain a cabinet temperature in the range of 4°C to 7°C, and once its ice bank is fully charged, it can maintain that temperature for more than 10 days. At the beginning of the project, of the devices available, the Sure Chill® had the largest vaccine capacity, was close to approval by WHO, and had the longest autonomy of any of the solar direct-drive refrigerators. ("Autonomy" describes the length of time that the refrigerator can maintain vaccine-safe temperatures with no or low solar input.) Long autonomy was important for the northern site in the Optimize in Vietnam demonstration. The Sure Chill® was prequalified by WHO in September 2011.

7.3. Implementation

This section describes how the Sure Chill® demonstration was implemented in Vietnam. Table 17 describes the project timeline and major milestones.

Table 17. Sure Chill® demonstration timeline

Year	Month	Milestone
2011	January	True Energy refrigerators ordered.
	April	Refrigerators arrive in country and delivered to Thanh Ba and Thanh Phu districts.
	May	Protocol finalized, devices installed, and users trained.
	August	First monitoring visits. Temperature data reviewed. NEPI decides to recommend vaccine storage in Thanh Phu (south) but to collect data for another three months in Thanh Ba (north) to monitor performance during cooler months.
	November	Second monitoring visits. Temperature performance good; high humidity conditions in refrigerator causing a lot of condensation. True Energy will redesign the shelf.
	December	Both refrigerators broke down due to failure of compressor controllers. True Energy traveled to both sites to conduct the repair before the end of the year.
2012	February	Third monitoring visits. Review of data showed excellent performance, even during very poor solar conditions in the north.
	May	Final monitoring visits; data collected.
	June	New problem with mold in vaccine boxes stored in the refrigerator. True Energy informed.
	August	Refrigerator in north broken down. Optimize/NEPI team discovered that one of the compressors has failed. True Energy informed. Trial of plastic boxes to control mold problem begins.
	September	Refrigerator in south broken down. True Energy calls an urgent meeting with compressor and controller company Danfoss (now Secop).
	October	True Energy travels to both sites to replace the refrigerators with new models. Danfoss (Secop) diagnostic testing reveals a component in the compressor that seems to be causing the failures. Observation shows that the plastic boxes protected vaccine boxes from mold during two-month trial. Official end of project. Optimize will continue to support NEPI by helping to replace the compressor controllers when they are ready from Danfoss (Secop) in early 2013.

Abbreviation: NEPI = National Expanded Programme on Immunization.

Optimize installed and evaluated the Sure Chill® refrigerator in two district PMCs—one in Phu Tho province (north) and the other in Ben Tre province (south). Each of the two power systems installed included two 235-watt power solar arrays, tilted at 21 degrees to the south in Phu Tho province and 15 degrees to the south in Ben Tre province. At both sites the solar modules were installed on the roof, where there was no shading to interfere with solar collection.

Using digital loggers, the team monitored ambient and refrigerator temperatures, refrigerator energy consumption, solar radiation, and energy generated by the solar panels. The team visited the project sites approximately every three months, and used questionnaires to gather data related to the acceptability and cost of the technology.

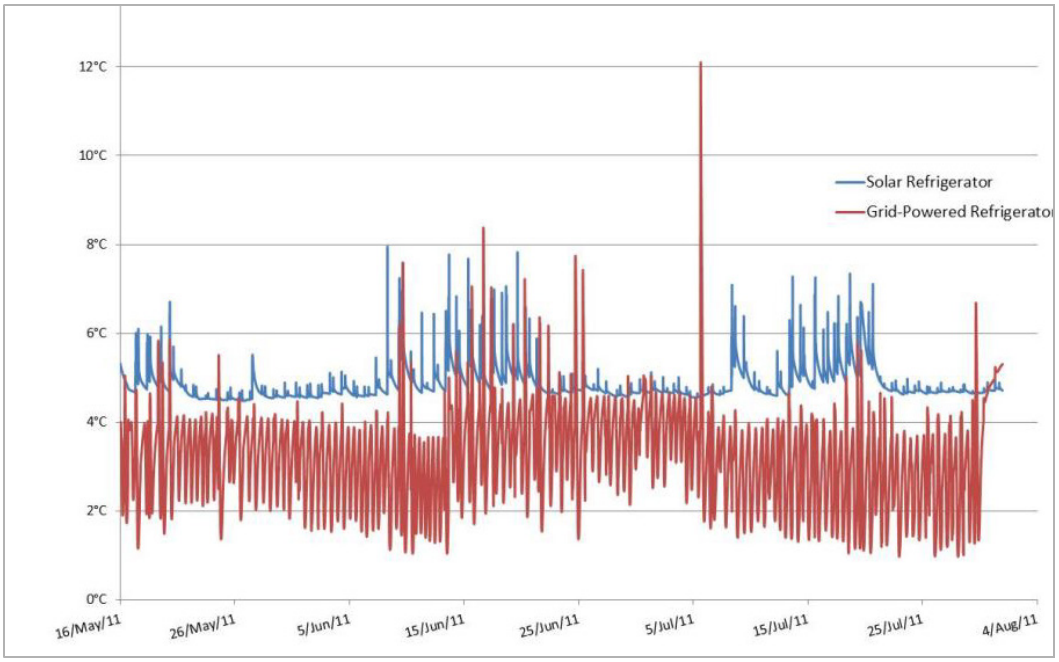
7.4. Results

7.4.1. Temperature performance of Sure Chill®

The Sure Chill® solar refrigerator maintains extremely stable temperatures. For the refrigerators in both the northern and southern provinces, the temperature recorded in the refrigerator center fluctuated only between 4°C and 5°C for most of the operating period of one year. When the door is opened, the temperatures increase more at the top front of the refrigerator cabinet than in the center or the bottom. Generally, when the refrigerator was closed, there was less than 0.5°C difference between the average temperature at the top of the cabinet and the average temperature at the bottom. For graphs showing the temperature recordings in both refrigerators during the project period, please see Appendix E.

The periodic temperature fluctuation in the Sure Chill® is much less than that in typical grid-electric compressor refrigerators used for vaccine storage. Figure 11 compares the temperature performance of a solar refrigerator and a grid-electric vaccine refrigerator in Phu Tho. The Sure Chill® was successful at maintaining the temperature between 2°C and 8°C over a long period.

Figure 11. Comparison of solar refrigerator and grid-electric refrigerator temperatures in Phu Tho



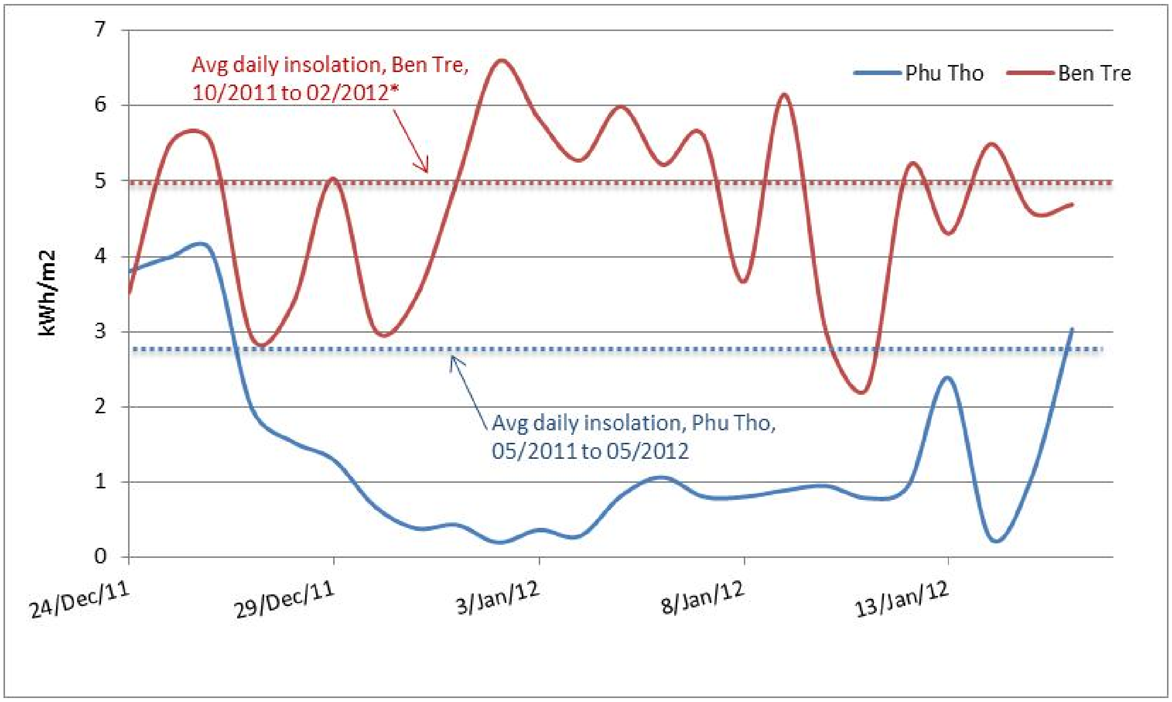
7.4.2. Performance in low-light conditions

"Insolation" is the technical term for incident solar radiation, or the amount of sunlight falling on a particular place at a particular time. At a cloudy location, insolation measured over time would be lower than that at a sunny location. For a direct-drive solar refrigerator, a certain minimum amount of insolation is needed in order for it to maintain proper temperatures in the vaccine compartment. This amount varies depending on factors such as the temperature in the room where the refrigerator is located and the amount of vaccine that needs to be cooled.

Periods of low insolation are commonly encountered from December through March in northern Vietnam. The average daily insolation measured over a one-year period in northern Phu Tho province was 2.8 kWh/m^2day. However, the winter average, measured from 1 December 2011 through 31 March 2012, was only 1.5 kWh/m^2day. Meanwhile, four months of winter insolation data in southern Ben Tre province averaged 5.0 kWh/m^2day (a clear sunny day will result in an insolation value around 6.0 kWh/m^2).

Prior to the demonstration, we did not know if there would be enough insolation in Phu Tho for the Sure Chill®, but even through a two-week period of low-light conditions, the Sure Chill® performed well, keeping temperatures in the safe range for vaccine storage. This is a very useful finding for other countries considering direct-drive solar refrigerators in cloudy locations, though it is noted that the cloudy period also coincides with significantly lower ambient temperatures, which lessons the cooling work the refrigerator has to do. Figure 12 shows the solar insolation measured in the north and the south over a three-week period that was particularly cloudy in Phu Tho. The dotted lines show the average insolation over a longer period for the two sites. For ambient temperatures, see the temperature charts in Appendix E.

Figure 12. Insolation measured at solar panels during three weeks in winter



7.4.3. System failures

Both solar refrigerators experienced major system failures in November/December 2011 and then again after the monitoring period, in summer and fall 2012. In most cases, it was the compressor controller that failed, though in one case there was a failure of the compressor itself. True Energy and Secop, the manufacturer of the compressors and controllers, have investigated the failures and determined that an internal component to the controller has been the main cause of the controller failure. A newly configured controller is being designed and will be manufactured in early 2013. When it is available, NEPI will replace all compressor controllers in the Vietnam refrigerators with the new controllers. The problem with the compressor was due to an early design of the evaporator plate support structure. Because many changes were adopted in the Sure Chill® design over the course of the Vietnam demonstration, True Energy decided to replace the refrigerators in Vietnam with new models, which were donated and installed in early November 2012. The new models incorporated 26 modifications as a result of the lessons learned from the experience in Vietnam. Changes were made to improve cooling efficiency, ease operation for installers and users, and increase robustness. This has highlighted the importance of monitoring early field performance of new refrigerator technology in order to make final refinements to the design for proper operation in real-life settings.

7.5. Acceptability and feasibility

The five respondents who were interviewed about the solar refrigerator categorized it as "highly acceptable" (4) and "acceptable" (1).[i] (The evaluation scale for acceptability and feasibility questions is included on page 15.)

7.5.1. Reasons for acceptability and feasibility

All respondents were asked what factors contribute to and what factors diminish the acceptability and feasibility of the solar refrigerator. Table 18 lists the factors given by respondents.

Table 18. Solar refrigerator technology—acceptability and feasibility responses

Factors that contribute to acceptability/feasibility	Factors that diminish acceptability/feasibility
• Very stable temperature, which makes it secure for vaccines. • No freezing temperatures. • No need to worry about vaccines during power cuts. • Saves electricity cost. • Functions even in winter when the weather is cloudy (north).	• Too much condensation in the refrigerator, making everything in it very wet. • Difficult and scary to climb to the roof to clean the solar panels. • No one available with the right knowledge and experience to fix the refrigerator if it breaks. • Need more capacity at districts for campaign vaccines. • Price makes large-scale uptake of this technology unfeasible in Vietnam. • It is loud.

The most commonly cited reasons for the acceptability of the solar refrigerator included its convenience and functionality, that it was user friendly, and that it worked to maintain stable temperatures for vaccine storage. One respondent explained the stability it demonstrated:

> *Although the power source is from solar energy, even when the weather is very cloudy and cold it still provides stable temperature.*
>
> Implementer, district level

Being independent from the electric grid was important to users in areas that encounter power cuts, as it eliminated the need for special vaccine monitoring during those times. As one respondent stated:

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[i] This respondent reported that the Sure Chill® solar refrigerator was "accepted at a low degree," out of the five options given: Very acceptable, acceptable, don't know, unacceptable, and very unacceptable.

With this refrigerator, there is no fear of power outage, just watching it twice a day. Besides, the normal refrigerator requires the vaccine-handling procedure during power outage. It is fortunate as with this refrigerator that kind of plan is not needed anymore. Through the monitoring process either in winter or summer, the temperature is always stable. However, it is very important that the temperature of the refrigerator needs to be monitored every day to see it's still good or not.

Implementer, province level

Respondents also mentioned the benefits of saving electricity costs with the solar refrigerator:

One advantage is that it doesn't consume electricity, so it's suitable for difficult, remote areas, border areas and islands.

Designer, national level

7.5.2. Factors diminishing acceptability and feasibility

As mentioned in Table 18, there were several factors cited that diminish the acceptability of the solar refrigerator, including the condensation that builds up in the refrigerator:

Previously, there is condensation water found, it brought troubles, but since you installed it, it is good stability and standing water it is also fixed. Generally, when the refrigerator has been fixed, I see this is better, several times before the condensation water covered drug packaging (boxes).

Implementer, district level

Another frequently raised concern was who would provide the maintenance or do the repairs for problems that arose with the refrigerators:

For example, an incident would require the invitation of foreign specialist to come. Later on, in case of a similar incident which occurs not within the piloting the question is where to get that individual? I mean, it is difficult to find the one with technical know-how to conduct repairing.

Implementer, province level

7.5.3. Scale-up considerations

Respondents reported that the refrigerator should be continued either long term (5 to 10 years) or permanently (none chose to have it continued for less than 5 years). Reasons for each choice were varied; respondents seemed hesitant to make the choice based on the short test time, as this respondent explained:

Well, I think that should be kept going, over 10 years, and its quality of lifespan lasted for how long, it may not dare to say, the test is one year only…Indeed, if used well, it is the best in permanent usage, as long as possible.

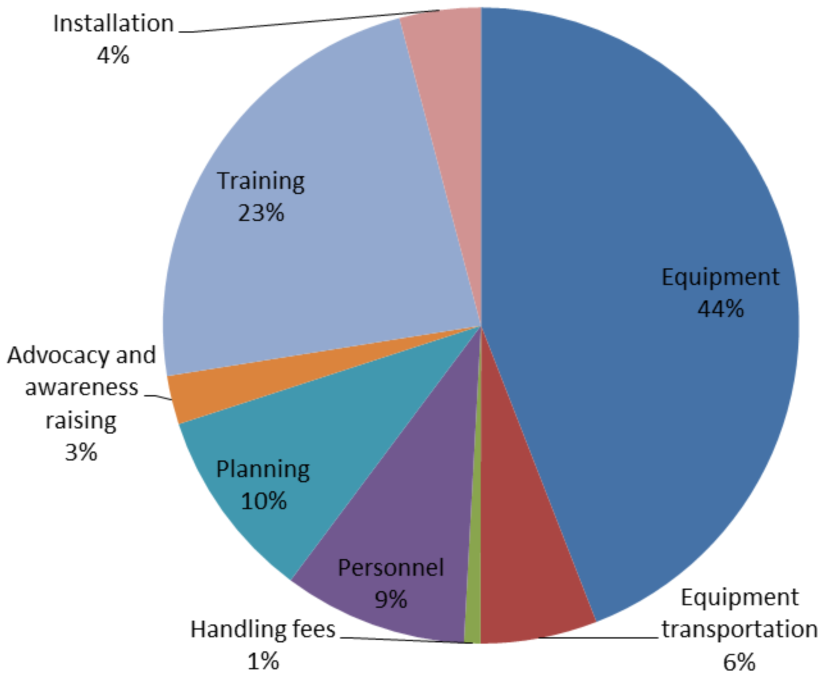
Implementer, district level

7.6. Cost

7.6.1. Investment costs

The financial investment costs for demonstrating district-level solar refrigeration totaled $40,872, and the average cost per facility was $20,436. Figure 13 shows a breakdown of those expenses. Although one of the refrigerators for the demonstration was donated, this analysis includes the full cost of both refrigerators. Similar to the Nano-Q, the largest share of the investment was for purchasing equipment (44 percent), followed by training (23 percent), planning (10 percent), and personnel (9 percent).

Figure 13. Cost profile for solar refrigerator intervention



7.6.2. Recurrent costs

For estimating recurrent total costs and cost per unit of Vietnam's supply chain by tier, we assumed a scenario in which both districts in our sample switched from using electric refrigerators to using only solar refrigerators. We assumed that there would be no change in the number of doses of vaccines delivered to the districts because of the intervention.

Table 19 provides the total recurrent costs before and after implementing the intervention. The estimated annual costs at the district level increased from $2,298 to $2,908 due to the higher annualized depreciation costs associated with solar refrigerators compared to those of the electric refrigerators. The solar refrigerators resulted in energy savings; however, the savings in energy costs were not high enough to offset the increase in depreciation costs, resulting in the cost per dose increasing slightly by $0.02 per dose.

Table 19. Average recurrent annual costs by input type for the solar refrigerator intervention at the district level

Input type	Baseline (US$)	With solar refrigerators (US$)
Labor and per diems	1,506	1,506
Depreciation of vehicles	34	34
Depreciation of cold chain equipment	631	1,293
Fuel costs	57	57
Energy costs	52	0
Vehicle insurance and maintenance	18	18
Total costs	**2,298**	**2,908**
Number of doses	32,475	
Cost per dose delivered at the district	0.08	0.10

The findings demonstrate how the introduction of solar technology shifted resource use, resulting in energy cost savings and a shift toward higher costs on capital depreciation. Over time, solar refrigeration can provide long-term savings in total energy costs and as new vaccines are introduced into the system, depreciation costs will be spread across a higher number of doses.

7.7. Challenges and lessons learned

7.7.1. Fungus growth on vaccine boxes

In spite of the high acceptability reported by users in May, a problem arose in June, after the acceptability and feasibility data had been collected, that resulted in the removal of all vaccines from the solar refrigerators: fungus began to appear on vaccine boxes stored in both refrigerators. Since the heat and humidity in Vietnam are very high, condensation was constantly forming on all the cold surfaces in the refrigerator, including the vaccine boxes. The inside of the refrigerator was exposed to moist air from the room whenever the refrigerator was opened—at least twice daily for temperature monitoring and more frequently during vaccine distribution days.

Unacceptably wet conditions were observed in both refrigerators as soon as storekeepers began to store vaccines there in fall 2011. Water was pooling on the shelves and dripping down from above, completely soaking the vaccine boxes. Users removed the vaccines and stopped using the refrigerators while the manufacturer responded with a change of shelf design and the addition of a plastic piece that fits below the ceiling inside the refrigerators and directs water to the back and bottom of the refrigerators. These changes improved the management of the water, but less than two months later, fungus appeared on the vaccine boxes (see Figure 14). In late August 2012, Optimize and NEPI staff began a pilot study using air-tight plastic boxes inside the refrigerators to hold the vaccine boxes and protect them from the moist air during daily openings. The boxes appear to have a protective effect against the mold growth, and further trials of this method are ongoing.

Figure 14. Fungus growth on vaccine boxes in solar refrigerators

Photo: NEPI/Nguyen Van Cuong

7.7.2. Technician support for refrigerator maintenance and repair

As reported in section 7.5.2, one of the factors users listed that diminishes acceptability and feasibility of the refrigerators was the lack of knowledge and experience of local technicians with the equipment. The project team faced this challenge as well, which made it difficult to quickly repair refrigerators when they broke down. We relied heavily on the manufacturer to help in these situations. While they were very responsive, for any larger projects in the future we recommend that local technicians be identified and trained so they can assist with technical issues.

7.7.3. Limited vaccine storage time

Another challenge of this demonstration was the relatively short period of vaccine storage in the refrigerators. Because it was important to first understand the temperature performance of each refrigerator before storing vaccines, we had a trial period at the beginning of the project during which we monitored refrigerator temperatures without the vaccines. Then, shortly after vaccine storage began, the fungus growth emerged (described in section 7.7.1 on page 58), resulting in the need to remove the vaccine and the need to again monitor temperature performance before returning the vaccines to the refrigerators. As a result, vaccines had only been stored in the refrigerators for a cumulative period of about three or four months when we collected our final data, and the fungus issue did not emerge until after the final monitoring visits. In the acceptability and feasibility research results, respondents were uncertain whether or not the intervention should be continued based on the short time that the solar refrigerator we tested. We recommend that future projects plan at least 18 months for refrigerator monitoring to allow for unexpected interruptions and to ensure that users can gain ample experience with the equipment during the project.

7.8. Next steps

The new refrigerators placed in Ben Tre and Phu Tho provinces by True Energy at the end of the project will remain in the districts for use as NEPI leaders designate. The manufacturer will supply new compressor controllers when they are available, and Optimize staff will assist NEPI with installation of these new parts. Optimize will also assist with ongoing study of the plastic boxes to protect against mold growth on the vaccine boxes. NEPI will not be expanding the use of this technology in the near future, primarily because recent investments have allowed them to purchase new refrigerators in most districts over the last five years, and there is currently no funding available for purchasing solar equipment. However, the experience with these direct-drive refrigerators has been valuable not only for NEPI but for potential users around the world, and NEPI will keep in mind the advantages of this equipment for future cold chain planning.

8. OTHER PROJECT ACTIVITIES

8.1. Effective Vaccine Management assessment

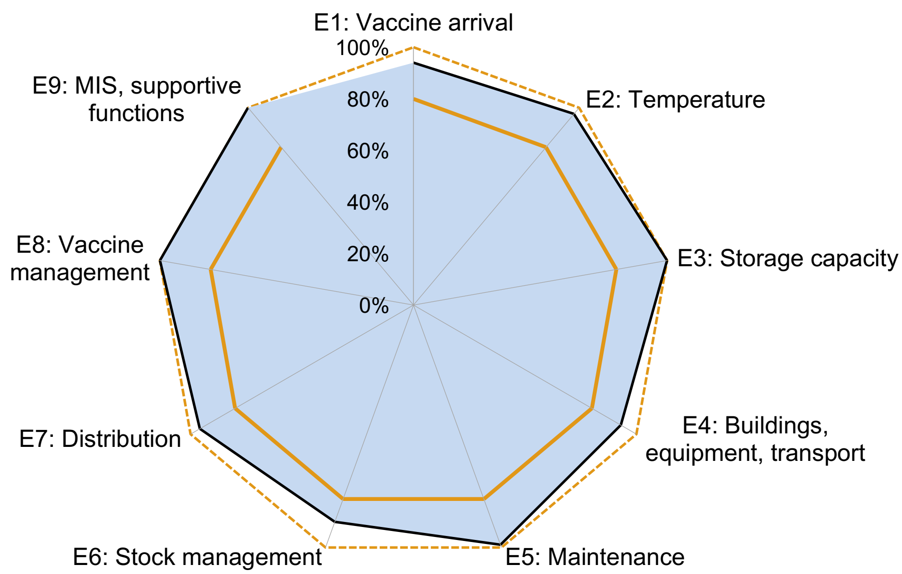
The EVM Tool was developed by WHO to provide countries with a means for systematic assessment of vaccine management processes and to help them identify and focus on areas for improvement in their vaccine management performance. An EVM assessment uses a structured questionnaire to evaluate countries' supply chains at different levels using specific criteria based on good storage and distribution practices. The tool also can be used as a supervisory aid to monitor and support individual facilities on a regular basis.

Optimize conducted an EVM assessment in 2009 as part of the first phase of the project in Vietnam. Figure 15 shows the scores at the national level, with the 80 percent baseline marked.

Figure 15. EVM scores at the national level in 2009

In 2012, NEPI carried out a follow-up EVM assessment to evaluate the effect of the system-strengthening activities described in "Development and dissemination of standard operating procedures" on page 63. The results revealed that key improvements have been made since the 2009 assessment (Figure 16).

Figure 16. EVM scores at the national level in 2012



For example, at the national level, NEPI made significant improvements in procedures for vaccine arrival, stock management, and distribution. The national store now meets the WHO-recommended target of 80 percent in all criteria compared to only two of nine criteria that met 80 percent in 2009. At the provincial level, results are strengthened for most criteria, most notably in vaccine management and storage capacity. Like the 2009 assessment, the recent EVM assessment has been a useful mechanism to help identify opportunities for improvement so that NEPI can prioritize and direct resources and training to strengthen the vaccine management system.

Key recommendations of the 2012 assessment include:

- Integrate the EVM Tool into regular EPI supervision at all levels, urging managers to reinforce and regularly check on areas identified as needing strengthening.
- Improve temperature monitoring by upgrading the monitoring equipment for vaccine refrigerators, cold rooms, and refrigerated trucks at the national, regional, and provincial levels with devices capable of continuous temperature monitoring.
- Raise awareness of the importance of freeze prevention for vaccines, retrain staff in the “shake test” for detecting freeze damage to vaccines, and provide freeze indicators for district-level refrigerators and for transport between province and district.
- At the district level, improve the timeliness of repairing broken cold chain equipment.
- Disseminate all SOPs to all levels so that staff are provided with specific and clear guidelines on vaccine management practices.

Training conducted by an Optimize consultant on developing and disseminating SOPs (described in section 8.2 on page 63) have provided NEPI staff with the skills and knowledge they need to confidently administer improvement activities in the EPI system. In 2012, NEPI staff managed the EVM assessment and conducted assessment visits. Their ownership of the EVM assessment process as well as the results leaves NEPI in a good position to make the best use of the tool.

Summary reports of the 2012 EVM assessment in both Vietnamese and English are available from NEPI by request. Refer to section 1.2 on page 2 for contact details.

8.2. Development and dissemination of standard operating procedures

One of the key findings of the first EVM assessment performed in 2009 in Vietnam was that NEPI should develop a well-documented system of high-quality SOPs for vaccine management at every level. Based on the EVM results, NEPI prioritized eight procedures for developing written SOPs. International cold chain management consultant Andrew Garnett conducted a three-day training with a group of national- and regional-level staff on best practices in the development and dissemination of SOPs. NEPI then worked to develop the content of the eight SOPs, and used a workshop setting to invite detailed input and feedback on each SOP from regional and selected provincial EPI staff. The SOPs were then published in a booklet and distributed to all EPI centers from the national to district level. NEPI will conduct training of trainers sessions over the following months to disseminate the revised SOPs.

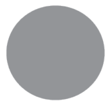
The following SOPs were completed under this program:

- Vaccine arrival at national level.
- Vaccine arrival and distribution at regional level.
- Vaccine arrival and distribution at provincial and district levels.
- Vaccine storage in cold room.
- Vaccine storage in refrigerator.
- Loading vaccine into vaccine carrier.
- Vaccine storage during immunization session.
- Maintenance of vaccine refrigerator and freezer.

8.3. Encouraging vaccine vial monitor adoption

VVMs were developed in the early 1990s by PATH in collaboration with a temperature-indicator company, Lifelines Technology (now Temptime). The VVM is a small label used on a vaccine vial that indicates how much heat exposure the vial has sustained over time. Instructions for using the VVM are shown in Figure 17. VVMs are extremely useful in circumstances when the cold chain has been compromised during transit or due to a power outage—it takes the guesswork out of assessing how much heat exposure is too much and it can prevent unnecessary wastage as well as ensure that vaccines are effective when administered.

Figure 17. Example VVM instructions for use

Start point		Square lighter than circle. If the expiry date has not passed, USE the vaccine.
Endpoint		Square matches the circle. Do NOT use the vaccine.
Endpoint exceeded		Square darker than the circle. Do NOT use the vaccine.

VVMs were first used in 1997, and their adoption has been increasing ever since. However, up until now, domestic manufacturers in Vietnam have not used VVMs. Since most vaccines used in Vietnam's immunization program are domestically produced, this prevents Vietnam EPI health workers from benefitting from VVMs. Also, since VVMs are required by the United Nations Children's Fund for international vaccine procurement, the absence of VVMs prevent Vietnamese manufacturers from exporting their products to other countries.

Optimize was eager to support the adoption of VVMs by a Vietnamese vaccine manufacturer. Activities supported by the project included organizing a national workshop and contracting for technical support to the manufacturer, Polyvac. Polyvac also obtained a donation of the VVM labeling equipment from the Japan International Cooperation Agency. An Optimize cost analysis showed that VVM use can result in modest savings for higher-cost, relatively heat-stable vaccines such as pentavalent. However, in modeling scenarios that would result in the large-scale wastage of vaccine without VVMs, the model indicates significant savings when VVMs are added because the model assumes that not all the vaccine would reach their heat exposure limit under those circumstances. Examples of this scenario include national disasters that result in widespread and long-lasting power outages.

In addition to cost savings, VVMs can enable improvements in vaccine coverage by allowing workers to remove vaccines from the cold chain for certain types of immunization outreach. For instance, by using VVMs, health care workers can keep HepB birth doses at CHCs for several days without cooling, which allows vaccine access immediately after the birth of babies delivered at CHCs or in homes. In 2005, PATH and NEPI piloted this model for HepB vaccine delivery in Thanh Hoa province and showed an increased rate of HepB birth dose immunization and positive safety and immunogenicity outcomes.[ii] However, this model for vaccine delivery cannot be safely implemented without the use of VVMs on vials.

Though Polyvac has put in place VVM application equipment and received technical support, during early trials they still had several technical challenges with applying VVM stickers. In

[ii] PATH. Out-of-cold chain delivery model for hepatitis B vaccine birth dose in four districts in Vietnam. Manuscript in draft.

addition, the MOH has not prioritized VVMs as important in their procurement of vaccines. If the Vietnam EPI is to benefit from VVMs, then more political and technical support is needed to move this initiative forward.

9. DISCUSSION

This chapter provides a summary of informal discussions that took place among various groups of project team members, NEPI and MOH staff, and implementers over the course of the demonstration projects and during the Optimize end-of-project workshop held in Hanoi in November 2012.

9.1. What were the most important lessons learned?

9.1.1. Plan more time for in-country technology demonstrations

All our demonstrations could have benefitted from more time to allow users to move beyond the learning curve and benefit from the lessons that come later in the life of technology use. We intended to have all our interventions in place by mid-2010, but various delays in the start-up phase, the slow process of collaborative development, and the heavy load of demonstrating four different technologies all resulted in delays, so the earliest intervention was not launched until May 2011 and the latest were not in place until early 2012. All final data collection took place from May to September 2012, so in some cases, we had only a few months of use on which to base the results of these technology demonstrations—certainly not enough time to take in all the lessons that could be gleaned from real-use demonstrations.

9.1.2. Though Optimize is focused on the future, NEPI has to focus on today

Though project Optimize had the luxury of looking to the future for inspiration, the solutions that we brought to NEPI had to be relevant in today's world. Interacting with a real-life immunization program, in a country as big as Vietnam, we learned that there was little opportunity to try to operate outside the regulations and norms of the current system. This was seen, for example, when the temperature of the Nano-Q cold box began to drop to less than 2°C. NEPI is not in a position to take on what they perceive as risks to the Vietnamese immunization program in order to support the project. Luckily, however, we were also able to offer a number of technologies that NEPI could use for dealing with today's challenges. For this reason, it was good that Optimize selected Vietnam, with strong and growing immunization programs (NEPI introduced pentavalent vaccine during the project term and is preparing a GAVI Alliance application for measles-rubella support as we close).

9.1.3. Countries should be prepared for challenges as well as successes

Testing new technologies is exciting, but it can also be frustrating if you forget that this type of work often results in failures along the road to success. Designers and engineers who do product development are used to this process of iteration and learning from the errors they make along the way. But in any country, MOH immunization programs expect their systems to work and can be discouraged and embarrassed when problems arise. For this reason, it is important to make sure that the national partner's leadership is prepared for some unexpected challenges along the way and that regular communication continues about this aspect of technology demonstration.

9.1.4. Software systems require more training and support than planned

The original plans to conduct user training and then launch into a monitoring phase did not provide enough support to the users since they had to learn new software programs that required significant changes to their work. Luckily, Optimize was flexible enough to be able to respond to the apparent need, and we conducted additional training sessions, convened user meetings, and provided extra user support so that immunization workers could, in most cases, become proficient in the software. Of course, there was wide variation in computer skills and experience across the user community, and not surprisingly, some individuals were better able to master the process than others. The implementation might have been smoother if we had included an IT professional on the project team to help better evaluate deliverables from the software developers and participate in design and troubleshooting. Also, it would have been better for users if the project had provided strategically located IT staff at field sites to support users on an ongoing basis. It is noted that training is an expensive component of the project, weighing in as the most expensive or second most expensive after equipment purchase/software development in each intervention. However, without investment in adequate quality training, new technology deployment is unlikely to be successful.

9.1.5. Leveraging local service providers can pay off

Project Optimize was able to identify strong providers of software development and solar installation services that were based in Vietnam. These were identified through careful procurement processes, with clearly identified needs and scopes of work, and a bidding process that sought proposals from multiple providers. There are several benefits of using local providers, where available:

- Language and cultural barriers are lowered—these providers can easily communicate directly with users, NEPI staff, and interfacing organizations. This greatly reduces the chances of miscommunication, which can hinder international projects.
- In the case of the software providers, they could be directly involved in user interaction, including training and project monitoring, which can increase the quality of the training and also provide feedback to the developer, which helps with bug resolution and functional software adjustments.
- NEPI can maintain access to these providers after the project finishes. Since the providers remain in Vietnam, and a relationship has been established between them and NEPI, it is easier for NEPI to access them later for project upgrades or additional services, helping to build sustainability into the project.

On the other hand, the team did struggle at times in the selection and management of the software providers. Because we lacked experience and technical knowledge related to software development, we were sometimes unsure what to expect of the contractors and how to evaluate the quality of their deliverables. As mentioned above, the inclusion of an IT professional on our team could have improved this aspect of the project.

9.1.6. Despite initial investment costs, new technologies can potentially reduce costs in the long term

The interventions demonstrated by Optimize in Vietnam required investment—most notably in equipment, software development, and training. However, recurring costs were marginally higher than the baseline system, with the cold chain interventions resulting in a slight increase in logistics cost per dose of vaccine delivered and information system interventions showing a negligible change. New investments in energy and labor-saving technologies that may have slightly higher costs per dose can be rationalized given Vietnam's high coverage levels and relatively low vaccine supply chain logistics costs for the current EPI vaccines. The vaccine supply chain costs as a share of the total value of vaccines for the EPI schedules declines from 93 percent to less than 25 percent when new, more expensive vaccines are introduced into the cost model schedule.

Supply chain costs associated with new technologies and practices as a share of total vaccine costs are likely to decline as more vaccines are introduced into the system, as long as storage and transport capacity is sufficient. Some investments, such as the initial investment in software development, will not need to be repeated when the system is scaled up. Similarly, even for capital equipment costs, such as for solar refrigerators, the recurrent costs that capture annual depreciation are driven down as the system moves to operating at full capacity.

The benefits conferred by each intervention on the immunization logistics system, either in high-quality storage conditions, freeing labor for non-reporting tasks, and even increasing on-time delivery of vaccines to the population could be propagated throughout the system by scaling up appropriate technologies to more of the EPI system. Our findings indicate that after initial investments, these improvements would not have a high recurrent cost burden on the immunization system.

9.1.7. Benefits of pilot projects are sometimes hard to measure

With the software implementations, Optimize had hoped to demonstrate improved reporting accuracy, increased timeliness of reporting, and decreased work burden on users, but these aspects of the technology are hard to measure in an objective, quantitative manner. It was not possible in our study to draw many conclusions from the data we collected in these categories. For future projects, more consideration should be given to showing these aspects of software technology impact.

9.2. What were the effects on Vietnam's immunization program?

As a result of working with project Optimize, NEPI has experienced several benefits:

- NEPI recognizes the benefits that a well-built software program could have on the information system management within their program. NEPI relies on reporting of a great deal of information from all over the country, and there are some distinct advantages of digitizing this information. However, to make sure it was done correctly, the effort needed investment and oversight. Optimize was able to contribute a critical mass of capital and international expertise while leveraging highly skilled software development resources within Vietnam to bring success to this effort. The VaxTrak system in particular is well poised for successful expansion if additional investment can be identified.

- NEPI has gained experience with a few different types of cooling technologies, and due to temperature monitoring results, has a clearer vision of temperature conditions in the cold chain. It has learned the value of continuous temperature monitoring and the importance of freeze prevention. Because the immunization program is administered all the way out at the commune level, NEPI was already aware that different locations face different challenges, and when it comes to cooling equipment, one size does not fit all. NEPI now has first-hand experience with solar direct-drive as well as passive-cooling equipment, and has some ideas of the pros and cons of each, as well as those of traditional electric vaccine refrigerators. This can help NEPI as it evaluates different possible technologies for future investments in the cold chain.
- NEPI has taken advantage of the opportunities that Optimize has presented by using the EVM Tool to conduct two EVM assessments—the second was self-driven. This strengthened staff knowledge and practices system wide through the development of new SOPs for key vaccine management processes. Also, it boosted freeze-prevention awareness and led to an upgraded temperature monitoring system at the national, regional, and provincial cold stores.

10. CONCLUSION

NEPI in Vietnam has been an extremely strong partner in project Optimize's global quest to explore immunization systems and technologies for tomorrow. The work we have done has yielded valuable lessons about several different classes of new technologies. Thanks to NEPI's commitment and diligent work over the last three years, we have:

- Opened the door to the future of electronic data management for NEPI's stock management and monthly reporting systems, as well as IR data. The software solutions we have demonstrated have strong potential for scale-up.
- Shown that one direct-drive solar refrigerator has extraordinary capability to perform under poor solar conditions, as well as uncovering a serious defect in the electronics of the refrigerator, the resolution of which will improve the device for future users in other countries.
- Built capacity among national and regional program staff for cold chain system assessment, as well as individual intervention monitoring and evaluation. These skills will serve the program well in the future.

In most cases, the users interacting with the Optimize technologies at all levels were very open to participating in the demonstrations and could recognize the benefits that we were trying to evaluate. They demonstrated dedication to the project protocols, collected valuable data, and provided thoughtful feedback. The project team is extremely grateful for the commitment and time devoted by these individuals.

As NEPI continues their journey into the future, which surely holds a fair mix of promise and challenge, we hope that the experience and skills they have gained will serve them well and that the lessons learned here will propagate, benefitting not only the immunization system of Vietnam, but of many countries around the world.

APPENDICES

A. Costing Vietnam's vaccine supply chain

Objectives

The ultimate objective of modeling the vaccine supply chain logistics system is to evaluate the cost and efficiency associated with Vietnam's vaccine supply chain prior to the Optimize project and to explore the potential changes to the supply chain system to meet future immunization needs.

The specific objectives of developing the vaccine supply chain logistics model are to:

1. Estimate the baseline costs of the current vaccine supply chain logistics system.
2. Estimate the costs associated with specific demonstration country interventions.
3. Estimate the costs associated with potential future scenarios that demonstration countries may consider.
4. Generate cost estimates that will be used as an input into measuring efficiency of the proposed changes to the vaccine supply chain logistics system.

Model structure

In order to model Vietnam's vaccine supply chain logistics model, we initially developed two models to capture the structure, resource use, and costs. The two models are briefly described below:

1. A supply chain model was developed in Arena, a logistics simulation software program designed to provide a visual model of the transport, cold chain, storage, and vaccine modules of the national supply chain and to create a platform for simulating changes to the existing vaccine supply chain logistics system and evaluating the associated costs.
2. An Excel costing tool consisting of a series of modules, informed by the structure of the Arena model. Each module was designed so that:
    a. Baseline and scenario information can be entered.
    b. Each component of the logistics system is included, such as transportation and cold storage, etc.
    c. Each level of the supply chain is included within each component.

The model was designed for the EPI vaccines in the routine system for 2009, including BCG, DTP, HepB, oral polio, measles, and TT and for 2010, when pentavalent vaccine replaced DTP and HepB for three doses of the schedule. Costs are estimated for a fully immunized child receiving 12 doses for the 2009 schedule, or receiving 10 doses for the 2010 schedule, and pregnant women receiving 2 doses of TT.

Data sources

In order to populate the model, we used a micro-costing approach to collect primary data from each level of the EPI system on all resources, such as capital equipment costs, personnel costs, supply costs, and other running costs related to different modes of transport and storage. Complementary secondary data were collected on the EPI schedule, vaccine type, quantity and prices, salaries, distances between supply points at each level of the vaccine supply chain logistics system, and other administrative data.

Primary data were collected from a convenience sample of facilities that reflect where the EVM assessments occurred or facilities where Optimize project interventions were underway. Data were collected in two phases. The first phase of data collection occurred between October 2009 and February 2010; during this phase, data were collected from the national store, all 4 EPI regions, 5 provinces, 10 districts, and 20 CHCs. The names of the facilities in the first phase are shown in Table 20. Data were also collected in January 2011, at all the health centers were the commune cooling interventions were implemented and the respective districts and provinces. The list of facilities in the Phase II data collection is shown in Table 21. The results in the preceding report reflect the estimates for the Phase II collection data sites because these correspond to the locations where most of the project Optimize interventions were implemented. We also used the Phase I costing results for the regional and national levels since data were only collected from these facilities in the first phase of data collection. The results including all the data collected in both phases are shown in Appendix C.

Table 20. Phase I costing data collection sites

Region	Province	District	Commune
North	Ninh Binh	Kim Son	Kim My Quang Thein
		Tam Diep	Yen Son Bac Son
	Phu Tho	Thanh Son	Vo Mien Tan Minh
		Lam Thao	Xuan Huy Hung Son
Central	Quang Tri	Vinh Linh	Ho Xa
			Vinh Thuy
		Huong Hoa	Huong Phung
			Huc
South	Ben Tre	Mo Cay Nam	Dinh Thuy
			Minh Duc
		Ben Tre City	Phu Hung
			Ward 6

Region	Province	District	Commune
Central Highland	Daklak	Krong Nang	Phu loc Eapuk
		Buon Ma Thuot City	Eakao
			Tan Thanh

Table 21. Phase II costing data collection sites

Region	Province	District	Commune
North	Phu Tho*	Phu Tho Town	Hà LÙc V n Lung
		Viet Tri City	Thanh Dinh Kim Duc
Central	Quang Tri*	Vinh Linh*	B¿n Quan Town Vinh Kim
		Trieu Phong	TriÇu S¡n TriÇu L ng
South	Ben Tre*	Thanh Phu	Tan Phong Th¡nh Phong
		Binh Dai	Châu H°ng LÙc Thu-n

* Data for this facility was collected in both surveys.

Supply chain cost functions

The two main functions that we consider for the costing are the storage function and the distribution/transportation function. Not all levels of the supply chain perform these two functions. For the storage function, typically the national vaccine store is responsible for the procurement of vaccines and dry goods supplies for the entire country and hence may also be the first storage point for the vaccines and supplies coming from manufacturers. At the lowest level of the supply chain, such as the CHC, they may not perform the storage function because the facilities do not necessarily have cold chain equipment required to store vaccine.

The distribution/transportation function can occur through a collection system or a delivery system, and both of these were observed in Vietnam from the provincial to the district level. For instance, in Phu Tho province, the two districts in our sample collected commodities from the provincial level and health centers collected from the district. Meanwhile, in Ninh Binh province, the province delivered vaccines and supplies to the district, and the health center collected from the district level.

Main cost components in the model

The main cost categories for storage and distribution functions are shown in Table 22. Storage costs include the annual depreciated value of the cold chain equipment; the cold chain energy costs; the labor costs attributed to procuring, ordering, and managing vaccine and dry goods stocks; costs for infrastructure; and maintenance costs for the cold chain equipment. Distribution costs include the direct labor time spent on transporting commodities and per diems; the depreciation of vehicles attributed to logistics; fuel, maintenance, and insurance costs for the vehicles attributed to logistics; and contracts for using third-party logistics companies or public transport for the trips. These costs by function were calculated separately for vaccines and dry goods, where dry goods included injection and reconstitution syringes and safety boxes.

The costs for staff time for vaccinating children were excluded because the focus of the analysis was on the costs of the supply chain. Other than electricity costs for running the cold chain, the analysis did not include any other indirect overhead costs, such as electricity for the office space, water, or telecommunications, etc. Supervision time may be underestimated. Appendix B contains a detailed description of the cost categories and an explanation of how each cost was estimated.

Table 22. Supply chain costs by function

Function	Cost	Function	Cost
Vaccine storage	Equipment depreciation	Vaccine transportation	Vehicle depreciation
	Energy		Fuel
	Infrastructure		Insurance
	Equipment maintenance		Maintenance
	Labor		Labor
Dry goods transportation	Vehicle depreciation	Dry goods storage	Infrastructure
	Fuel		Labor
	Insurance		
	Maintenance		
	Labor		

Throughput

The throughput was the annual number of doses of vaccines distributed to each level. When available, these data were obtained from stock-ledger data at each warehouse or facility during data collection and from vaccine arrival reports at the national vaccine store. When stock-ledger data were not available, we used population data, coverage data, and wastage rates to estimate expected demand. In addition to doses delivered, another throughput measure is the corresponding volume of vaccines distributed using the packed volume of each dose of vaccine and the value of the vaccines distributed using the vaccine prices.

Cost measures and supply chain metrics

Several cost measures and supply chain metrics can be calculated from the model that capture total and unit costs, and provide different ways of capturing the efficiency of Vietnam's supply chain system (Table 23 and Table 24). The building blocks of the cost analysis are the total and cost per dose at each level of Vietnam's system; however, costs can also be estimated by function or by input type. The aggregate supply chain logistics cost per dose from central-level origin to final CHC destination is defined as:

[Cost per dose at national store] + [Cost per dose at region] +
[Cost per dose at province] + [Cost per dose at district] + [Cost per dose at CHC]

Other metrics include the cost per volume and logistics cost as a percentage of the value of the vaccines.[iii] These estimates can help evaluate the performance of the vaccine supply chain system and capture the efficiencies of the system in storing and transporting vaccines and immunization supplies through the system. The latter estimate can be useful to inform reasonable rates for handling fees based on the value of the commodities.[iv]

Table 23. Cost measures estimated from the model

Cost	Description
Total annual supply cost	Annual total storage and transportation costs for facility.
Total cost by function	Total storage costs for the facility. Total transport costs for the facility.
Total cost by input	Labor costs. Cold chain equipment depreciation costs. Cold chain maintenance costs. Cold chain energy costs. Vehicle depreciation costs. Transport recurrent costs. Infrastructure costs.
Cost drivers per tier	The cost inputs or cost functions that account for the largest share of the supply chain costs.

[iii] DELIVER. *Monitoring and Evaluation Indicators for Assessing Logistics Systems Performance*. Arlington: DELIVER; 2006. Available at: http://deliver.jsi.com/dlvr_content/resources/allpubs/guidelines/ME_Indi.pdf.
[iv] Baruwa E, Tien M, Sarley D. *Zambia: ARV Supply Chain Costs: A Pilot of the Supply Chain Costing Tool.* Arlington: USAID | DELIVER PROJECT, Task Order 1; 2010. Available at: http://deliver.jsi.com/dlvr_content/resources/allpubs/countryreports/ZM_ARVSupplyChainCost.pdf.

Cost	Description
Average supply chain costs	The average supply chain costs for each tier or for a subgroup of facilities in the same tier.

Table 24. Supply chain metrics

Cost measure	Notes	Formula
Cost per dose at the facility	Calculated at each facility.	Total annual supply chain costs divided by the annual number of doses of vaccines distributed.
Cost per dose	The core indicator for the model, aggregated across tiers. It measures the cost of moving a single dose of vaccine from the national store to the CHC.	Sum across facilities (cost per dose at the national store, regional store, provincial store, district store, and health center).
Cost per cm^3 of vaccines	Calculated for each facility and for vaccines only.	Vaccine supply chain costs divided by the volume of vaccines distributed to the facility.
Logistics costs as percentage of vaccines value	Calculated for each facility and for vaccines only. This is a ratio of the measure above on the cost per $1000 worth of vaccines.	Vaccine supply chain costs multiplied by 100 divided by the value of vaccines distributed to the facility.

Results

Table 25 shows the resulting estimated average total annual logistics costs by level. Total costs were highest at the national and regional stores, compared to lower average costs at the provincial, district, and commune levels. The estimated annual costs at the national level were approximately $65,000, with vaccine transport costs accounting for almost 50 percent of the costs. At the regional level, annual costs ranged from about $26,000 (for Central Highland region) to approximately $48,000 (for South region), and the average cost at the regional level was estimated at $39,000. Vaccine storage costs accounted for the largest share of costs at the regional level and also at all the lower tiers. At the time of data collection, none of the three provinces provided dry goods transportation to the districts and hence costs for this function were zero. The average cost of vaccine storage and distribution at the health center level were approximately $240 per year.

Table 25. Annual logistics costs by level

Logistics function	National (US$)	Average by level (US$)			
		Region	Province	District	Health center
Vaccine transport	32,653	12,571	932	97	44
Dry goods transport	2,749	2,087	0	73	3
Vaccine storage	29,400	19,726	4,455	2,066	179
Dry goods storage	0	4,422	40	63	11
Total annual cost	**64,802**	**38,807**	**5,428**	**2,298**	**237**

Figure 18 presents the cost profile broken down by each level of the system to capture cost drivers at each tier of Vietnam's vaccine supply chain. At the national level, contracts for vaccine transport were the largest share of the costs, followed by cold chain equipment depreciation. For the provincial level and lower, labor and cold chain capital depreciation are the main drivers of costs.

Figure 18. Cost profile by vaccine supply chain tier

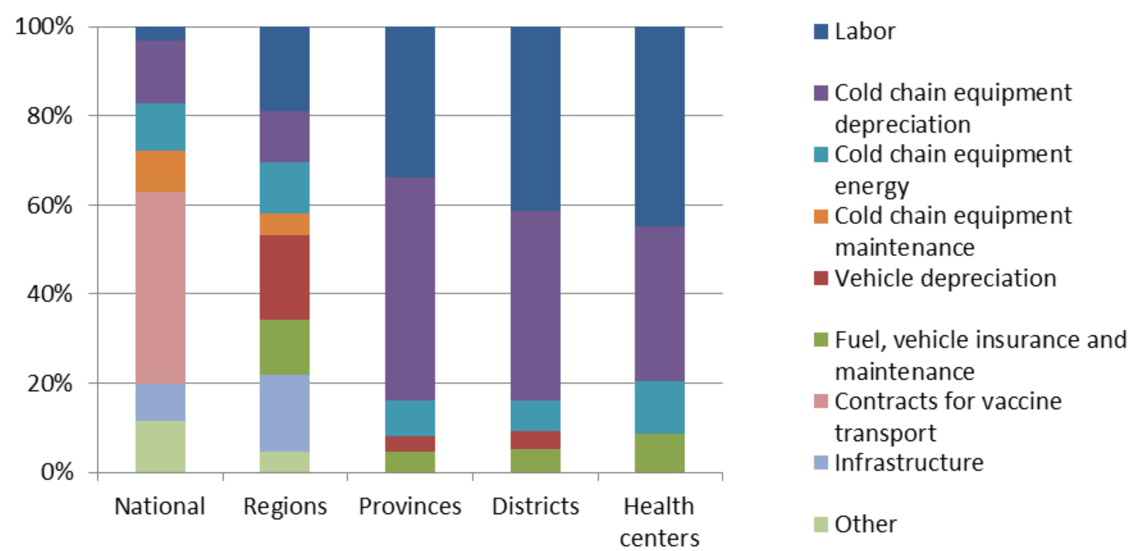


Table 26 shows the estimated cost metrics by level, for both the 2009 EPI schedule before the introduction of the pentavalent vaccine and for the 2010 schedule after the introduction of the pentavalent vaccine.

Table 26. Average supply chain logistics cost per dose by tier

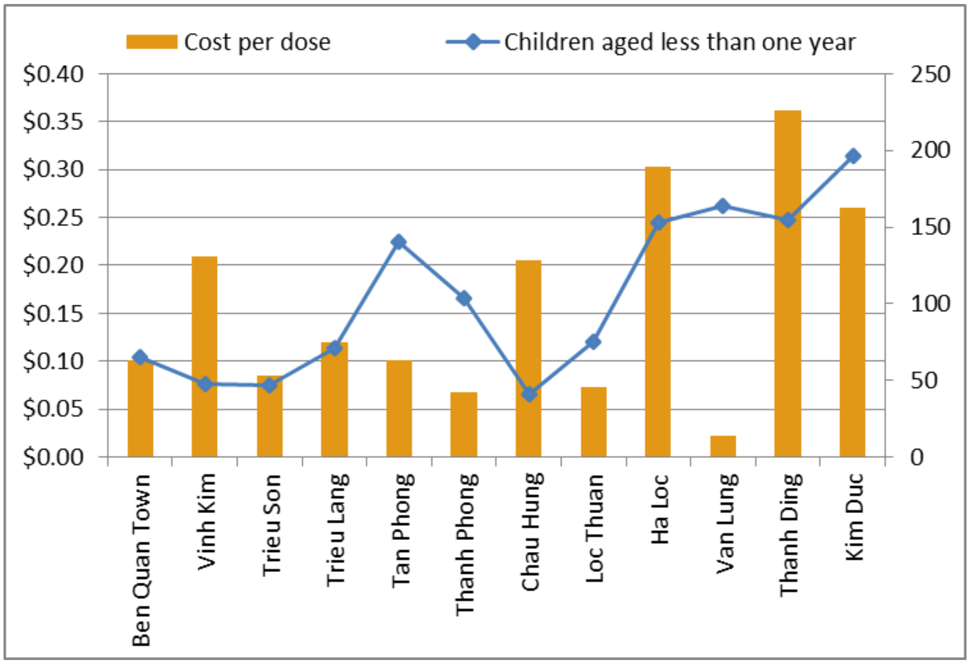
Tier	2009 schedule			2010 schedule		
	Cost per dose	**Cost per cm^3**	**% cost***	**Cost per dose**	**Cost per cm^3**	**% cost***
National	$0.003	$0.001	1.7%	$0.002	$0.001	0.4%
Regional	$0.01	$0.001	2.90%	$0.005	$0.002	1.2%
Provincial	$0.02	$0.005	14%	$0.02	$0.005	3.4%
District	$0.07	$0.02	51%	$0.08	$0.02	13%
Health center	$0.12	$0.03	94%	$0.16	$0.04	23%
Total cost per dose	**$0.21**			**$0.27**		

* Expressed as a percentage of the vaccine value.

The average supply chain cost per dose is lowest at the national, regional, and provincial levels, capturing economies of scale when large numbers of vaccines are being stored and transported relative to the fixed capital costs. The average supply chain cost of Vietnam's immunization program was estimated at $0.21 per dose, or a total of $2.92 per fully immunized child using the 2009 schedule. This accounts for approximately 59 percent of the fully loaded vaccine costs in the 2009 EPI schedule. Using the 2010 schedule, when the pentavalent was introduced, vaccine supply chain logistics costs per dose increased to $0.27 due to a reduction in the number of vaccines in the system because there were fewer doses per fully immunized child and lower wastage rates. This estimate assumes the same labor and transport costs associated with the 2009 schedule, although with fewer vials in the system, some of these costs may have been reduced. With a new, more expensive vaccine, the share of logistics cost as a proportion of the value of vaccines decreases significantly. The cost per fully immunized child increased to $3.23, but the logistics costs comprised only 24 percent of the fully loaded vaccine costs.

Figure 19 shows that relationship between the estimated cost per dose and the number of children aged less than one year at each of the CHCs in the sample. Generally, the larger the population served, the lower the cost per dose and this is because the fixed costs (like capital costs for cold chain) are spread over a larger population, lowering the estimated cost per dose. Some of the health centers did not have any cold chain and so their cost per dose was lower than those for other health centers serving similar size populations (e.g., TriÇu S¡ n CHC had a similar size population as Vinh Kim but it did not have a refrigerator). Also, the type of cold chain equipment owned at the CHCs affected the cost estimates, specifically, Hà LÙc, Thanh Ding, and Kim Duc CHCs were using the RCW 50 EG, which runs on gas and has a higher replacement price and hence both their energy and depreciation costs were higher than the other health centers using electric refrigerators (or cheaper domestic refrigerators).

Figure 19. Relationship between estimated logistics cost per dose and number of children aged less than one year at CHCs



B. Major supply chain input categories

The major supply chain cost categories included in the model for the storage and distribution functions are described below.

Labor

Facility personnel with duties in EPI logistics were asked to estimate the amount of time they spent on the list of activities summarized in Table 27. Staff members were asked how often each activity occurred (daily, weekly, or monthly) and how much time they spent on each activity during the specified time period. The cost of the labor for logistics was calculated as the percentage of time spent on logistics multiplied by the annual salary.

Table 27. List of logistics activities for labor use survey

Procurement for facility	Procurement for lower-level facilities	Transportation	Stock monitoring	Other activities (national store only)
Estimating and forecasting needs for the facility.	Estimating or preparing orders and completing paperwork for lower-tier orders.	Transporting to lower tiers, or collecting from higher tiers, planning the distribution system including scheduling the deliveries, management of vehicle fleet for distribution.	Temperature monitoring of cold chain equipment with vaccine stocks.	Advertising and evaluating tenders, awarding contracts, working on contracts related to logistics.
Preparing and completing paperwork for orders.	Entering orders from lower tiers into the computer.		Issuing orders to lower tiers, or packing orders for distribution.	Supervising people involved in logistics activities.
Entering orders into the computer.	Checking and approving orders from lower tiers.		Receiving orders from higher tiers, updating stock ledgers, and organizing and packing orders.	
Checking and approving orders.				

Cold chain equipment (annualized depreciation)

The economic capital costs of the cold chain equipment used for storing vaccines was calculated. The standard formula (the current replacement cost of the cold chain equipment divided by the annualization factor) was used. A discount rate of 3 percent was used. We assumed that cold rooms and freezer rooms had an economic life of 15 years, refrigerators and freezers had an economic life of 10 years, and so did the cold boxes and vaccine carriers.

Cold chain recurrent costs—energy and maintenance

The recurrent costs for cold chain included the energy costs per year and the equipment maintenance costs. The energy costs were calculated as the energy usage per day (e.g., kWh per 24 hours for electric equipment) multiplied by 365 days multiplied by the unit price of energy. The maintenance costs were the reported maintenance expenditures for cold chain equipment or the cost paid in the tender for cold chain maintenance.

Transport costs

The economic capital costs of vehicles used for vaccine and the transportation of dry goods were also calculated. We assumed an economic life of the vehicle, based on distance traveled during its economic life. The annual economic capital cost was calculated as the replacement price of the vehicle divided by the distance traveled during its economic life, to get the estimated depreciation per kilometer. This estimated deprecation per kilometer was then multiplied by the distance traveled for vaccine and dry goods collection to estimate the depreciation attributable to logistics.

Recurrent transport costs—fuel, maintenance, and insurance

The recurrent costs for transport were the fuel, maintenance, and insurance costs and these were also estimated as costs per kilometer. The fuel costs per kilometer were estimated by dividing the fuel price by the fuel efficiency (expressed as kilometers traveled per liter). Insurance and maintenance costs were estimated by dividing the annual expenditure by the annual distance traveled by the vehicle for all uses, to get the costs per kilometer. There was no consistent reporting of maintenance and insurance costs and so we used the data that were available to estimate the costs per kilometer, and applied the same rate across facilities with missing data. These costs per kilometer estimates were then multiplied by the distance traveled for logistics to estimate the costs attributable to logistics.

Storage space

This was the cost to lease the space allocated for cold storage or dry goods storage. Only the national store and regions had dedicated spaces, while the other tiers had shared spaces and so the infrastructure costs were only calculated for these upper tiers.

C. Demonstration project start-up and investment costs by intervention

Table 28. Investment cost for each intervention

Cost category	Intervention (US$)				
	Solar refrigerator	Passive cold box	VaxTrak software	Immunization registry	Fee-based software
Planning	3,992	3,992	3,992	3,992	4,938
Advocacy and awareness raising	1,011	1,011	1,011	1,011	5,856
Equipment procurement	20,786	15,483	12,694	3,205	2,057
Personnel	3,826	1,706	1,092	355	240
Product development and testing	0	0	64,814	9,054	17,943
Training	9,566	7,604	12,811	9,662	23,042
Installation	1,691	4,579	14,896		
Total	**40,872**	**34,376**	**111,311**	**27,279**	**54,076**
Cost per facility	**20,436**	**2,865**		**1,516**	**n/a**

D. Temperature recordings from Savsu Nano-Q passive vaccine coolers

Figure 20. Temperature recordings from Savsu Nano-Q passive vaccine coolers in Phu Tho province

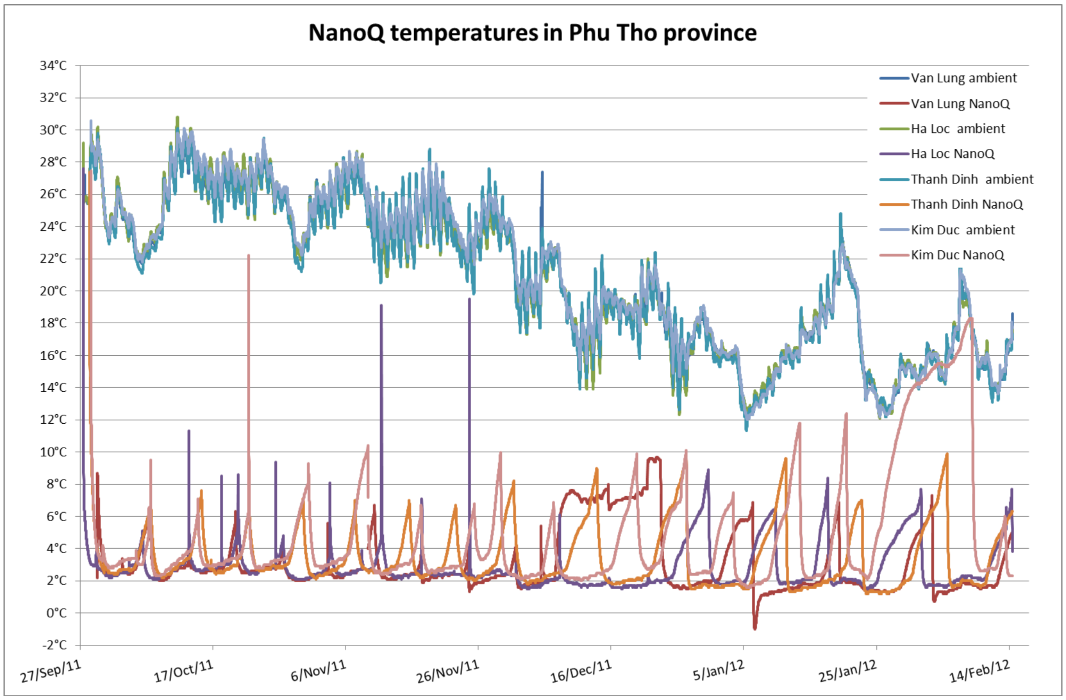


Figure 21. Temperature recordings from Savsu Nano-Q passive vaccine coolers in Ben Tre province

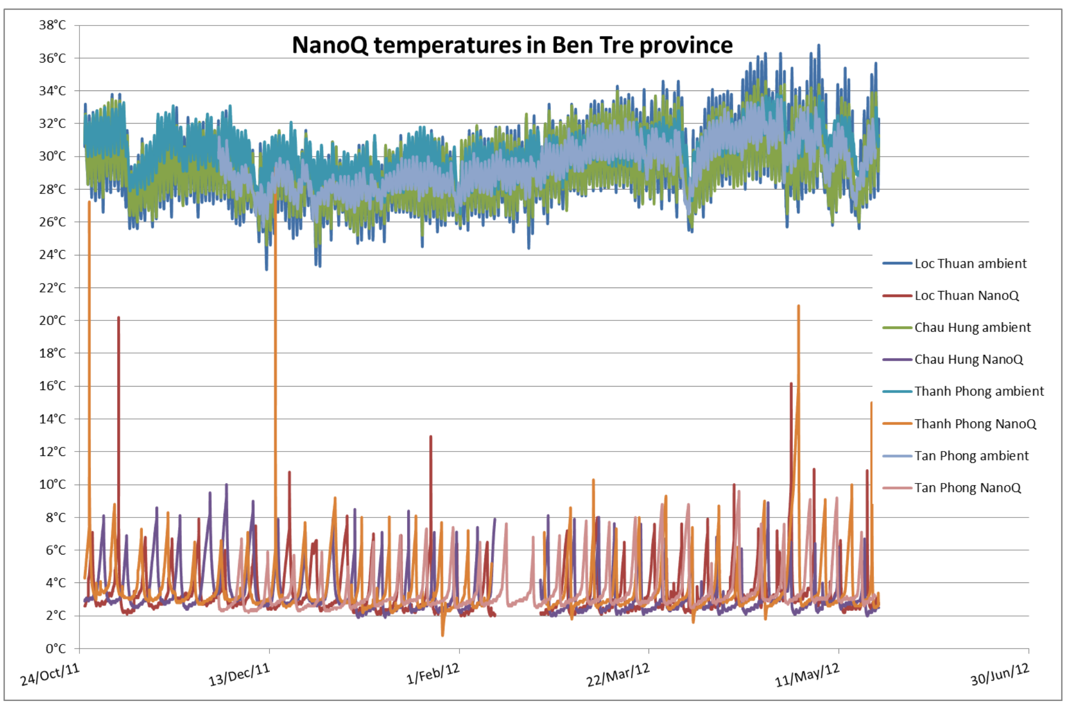
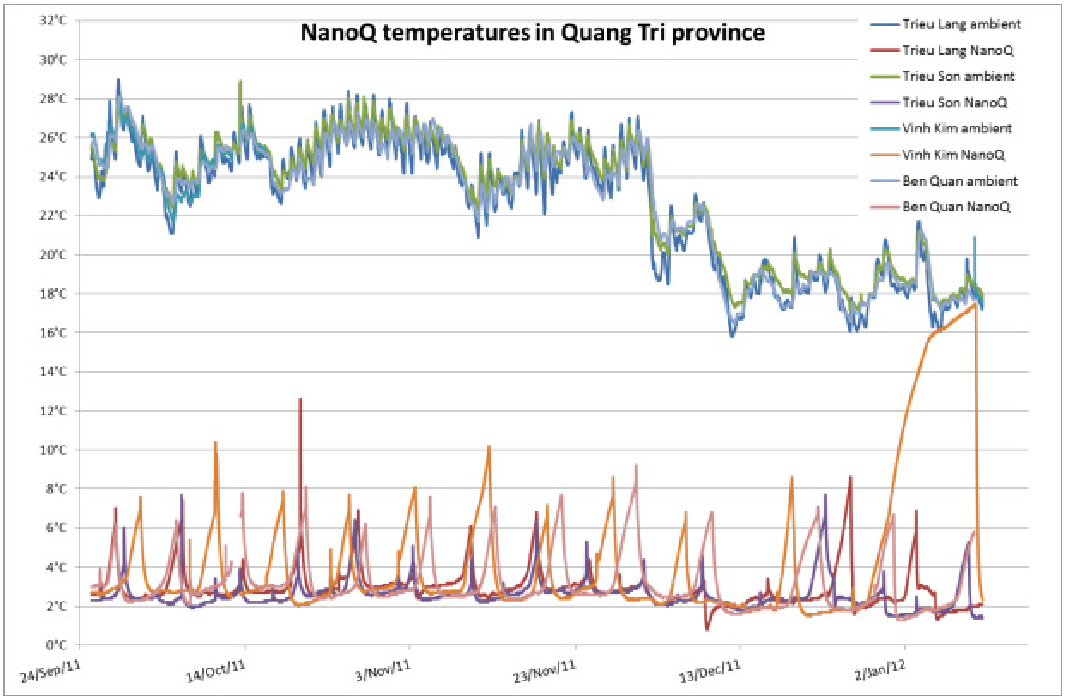


Figure 22. Temperature recordings from Savsu Nano-Q passive vaccine coolers in Quang Tri province



E. Temperature recordings from solar refrigerators

Figure 23. Temperature recordings from solar refrigerator in Phu Tho province

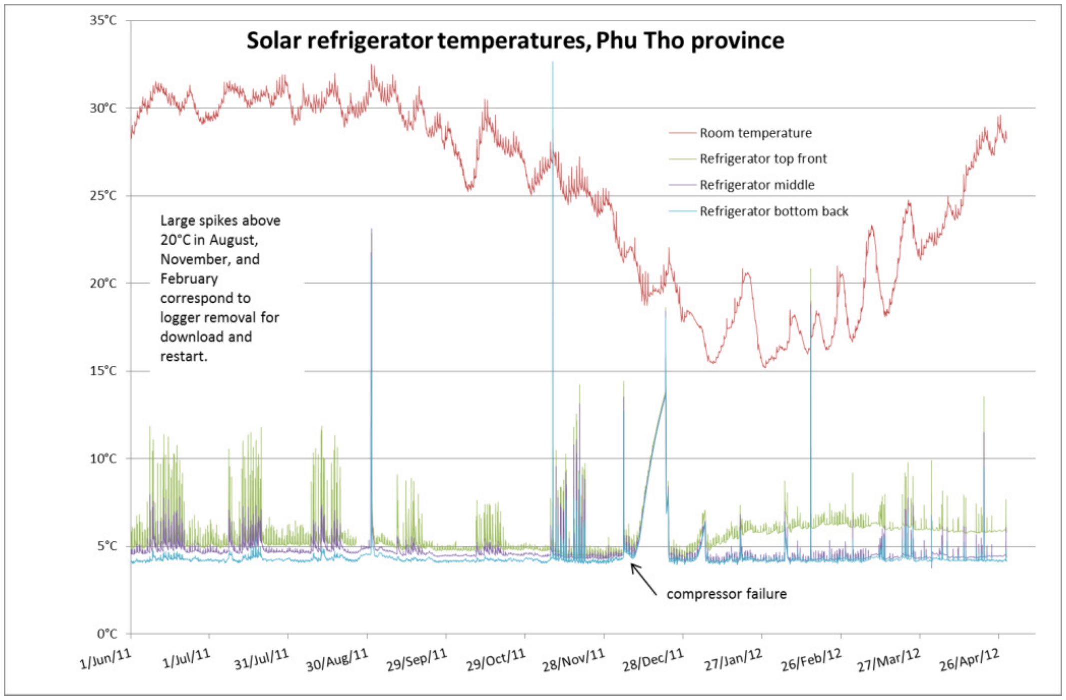
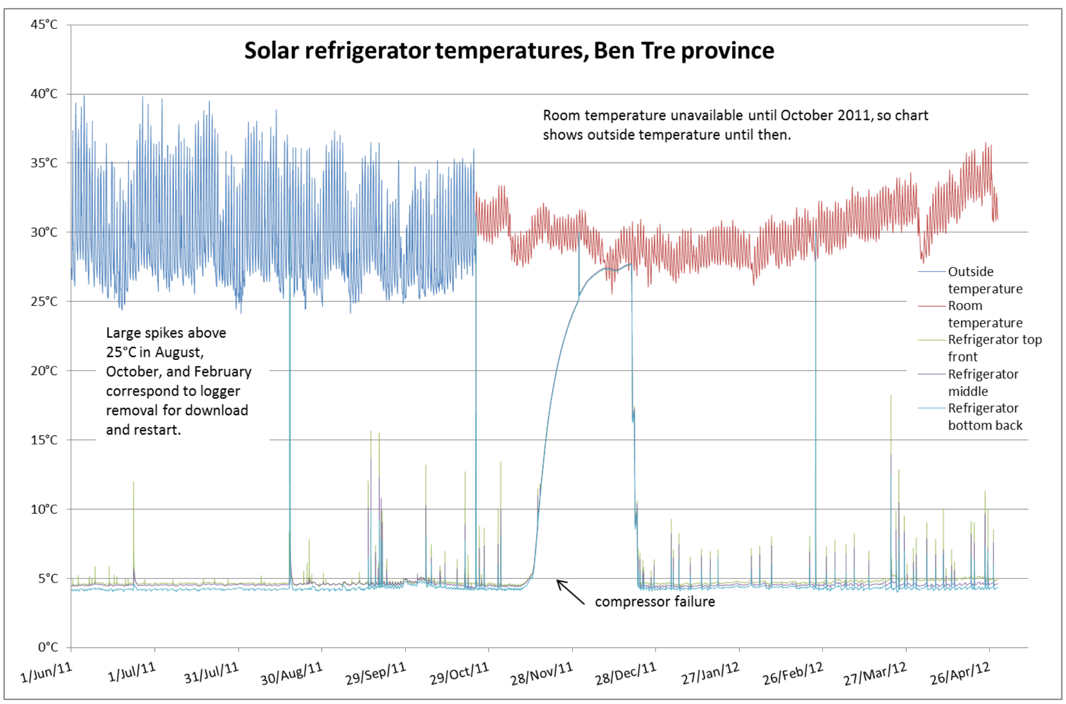


Figure 24. Temperature recordings from solar refrigerator in Ben Tre province



F. Acceptability and feasibility assessment

An assessment[v] of the acceptability and feasibility of the Vietnam interventions was conducted to explore the perceptions of the stakeholders engaged in the development and implementation of the project Optimize demonstrations in Vietnam. The goal of this assessment was to describe relevant intervention characteristics and explore the perceptions and practices of stakeholders engaged in the development and implementation of interventions. From these experiences we hoped to identify key advantages and challenges associated with project-supported interventions.

This assessment seeks to measure stakeholder perceptions of the acceptability and feasibility of the five interventions in Vietnam: VaxTrak, Fee-Based Immunization Reporting, Digital Immunization Registry, Solar Refrigerators, and Passive Cooling. The terms, "acceptability" and "feasibility" can often overlap. For the purpose of this research, the two terms are defined as follows to help keep them as distinct as possible.

- Acceptability: Acceptability refers to what the stakeholder likes and dislikes about an intervention. An acceptable intervention is desirable and satisfactory.

  Examples: An intervention might be considered **acceptable** because of benefits to mothers and infants with better access to immunization, or because of benefits to MOH immunization staff through reduced workload. An intervention might be considered **unacceptable** if it has a small benefit for mothers and infants or low benefits to MOH immunization staff through added workload or resources.
- Feasibility: Feasibility refers to the difficulty, or ease, with which the stakeholder can implement required intervention activities. If an intervention is feasible, it is practical and easy to carry out and achieve.
- Examples: A **feasible intervention** is practical to achieve with the available time, staff, and resources. Think about the introduction of a new vaccine. A feasible scenario would be the introduction of a new vaccine that comes in vials similar to existing vaccines, and that is handled in the same cold chain conditions as existing vaccines. An **unfeasible intervention** is not practical to achieve with the available time, staff, and resources. An unfeasible scenario would be the introduction of a new vaccine with packaging so large that you cannot fit enough doses in the district refrigerator, it requires dry ice to be transported, and the shelf life is only a few weeks long.

This assessment was conducted using qualitative methods. The internal Vietnam research team used a variety of locally adapted methods to collect and analyze qualitative data obtained from intervention stakeholders. The methods used in completing this evaluation included semi-structured interviews with various levels of stakeholders. The data collection phase took place in May-September 2011. Each respondent gave verbal consent, and was asked to be recorded.

The team conducted interviews with three categories of respondents: implementers (health care workers), decision-makers, and designers. Responses were analyzed using Atlas.ti software, and results were triangulated with monitoring data. The findings from the acceptability and feasibility

[v] This assessment was deemed "non-research" in accordance with PATH's Research Determination Committee policies.

assessment contribute to the five components of the global project Optimize monitoring and evaluation framework.