Comparison of Costs Incurred in Dedicated and Diffused Vaccine Logistics Systems

Cost-Effectiveness of Vaccine Logistics in Cabo Delgado and Niassa Provinces, Mozambique

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Acronyms

DDS	Direcção Distrital de Saúde / District Department of Health
DHS	Demographic and Health Survey
DPS	Direcção Provincial de Saúde / Provincial Department of Health
DPT-Hep B3	Diphtheria-pertussis-tetanus-hepatitis B
EPI	Expanded Programme on Immunization
FDC	Fundação para o Desenvolvimento da Comunidade / Foundation for Community Development
MISAU	Ministerio da Saúde / Ministry of Health of Mozambique
PAV	Programa Alargado de Vacinação / Expanded Programme on Immunization
US	Unidade Sanitária / Health Unit

Acknowledgements

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I. Executive Summary

The Project to Support PAV[1] logistics system, implemented by VillageReach, the Foundation for Community Development (FDC), and Mozambique's Ministry of Health (MISAU) in the Cabo Delgado Province of Mozambique from 2002-2007 showed significant cost savings over the operations of the vaccine logistics system operated by MISAU in Niassa province. The comparison showed an increased cost-effectiveness as measured in cost per child vaccinated with DPT-Hep B3 and increased cost-efficiency as measured in cost per vaccine dose delivered. The Project to Support PAV logistics system in Cabo Delgado employed an active logistic delivery system where vaccines were reliably delivered to the health units each month, while Niassa's vaccine logistics system consists of a mixed and inconsistent system combining collection and distribution based activities that vary by location and month. This report also makes specific cost recommendations for implementing the Project to Support PAV logistics system in the Niassa province.

The vaccine distribution system in Niassa operates under the current MISAU system organization with no transport or personnel resources dedicated exclusively to vaccine logistics. The Project to Support PAV in Cabo Delgado operated with vehicles and staff dedicated exclusively to vaccine logistics. Additionally, the vaccine logistics system in Cabo Delgado integrated supportive supervision and information management into the vaccine distribution.

The primary objective of the cost study was to compare the incremental costs of the vaccine logistics system used by the Project to Support PAV. In particular, understanding the costs of the changed system introduced by the external intervention is of considerable interest to MISAU, which must ultimately bear the costs of any elements of the VillageReach model that are incorporated into its own system.

The cost study found the following results:

The Project to Support PAV vaccine logistics system is significantly more cost-effective than traditional vaccine distribution systems.

- Because of greatly higher vaccine coverage rates (95.4% in Cabo Delgado compared to 70% in Niassa), the dedicated vaccine logistics system in Cabo Delgado was 17% more cost-effective, at $5.03 per child vaccinated with DPT-Hep B3 compared to $6.07 per child vaccinated with DPT-Hep B3 in Niassa.

The Project to Support PAV vaccine logistics system is more efficient than traditional vaccine distribution systems.

- The dedicated vaccine logistics system in Cabo Delgado was 21% less expensive per vaccine dose delivered than the Niassa system. The Niassa system cost $1.50 per dose delivered versus only $1.18 per dose delivered in Cabo Delgado.

The Project to Support PAV logistics system allocates more expenses to the actual cost of vaccines rather than to the distribution system.

- In the vaccine logistics system in Niassa, the purchase cost of vaccines and syringes comprised only 46% of total distribution system expenses, while in the Project to Support PAV system, they totaled 61% of the vaccine logistics system expenses.

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[1] In Portuguese speaking Mozambique, PAV is Programa Alargado de Vacinação, the Expanded Program on Immunization.

II. Overview of Study

In March 2002, the Mozambique Ministry of Health (MISAU), VillageReach and the Foundation for Community Development (FDC) began a five-year pilot project in Cabo Delgado province in northern Mozambique. The pilot project and the subsequent 2006 expansion into Nampula are referred to in Mozambique as the "Project to Support PAV." The Project to Support PAV strengthened the management, reliability and quality of the health system through improvements in the following areas:

- Service Infrastructure: information management, waste management, transport, and energy
- Logistics: stock control and security, forecasting and reporting, inventory management, delivery of health goods, cold chain maintenance and supervision
- Community and Health Worker Support: supportive supervision, data analysis, training, social mobilization

In November 2008, VillageReach released the results of an impact evaluation of the Project to Support PAV in Cabo Delgado. The results showed significant improvements in the project site. In 2003, the Demographic and Health Survey (DHS) reported a DPT-Hep B3 coverage rate in Cabo Delgado of 68.9%. In the 2008 evaluation, DPT-Hep B3 coverage had increased to 95.4% for children age 24-35 months. All other vaccines had similar increases resulting in a 92.8% coverage rate for children aged 24-35 months. Improvements in supply and inventory management were also recorded: at the end of the program less than 1% of health centers reported a stock out compared with 80% at program start.

While these increases in vaccine coverage rates seem impressive and significant, the improvements must be examined against the additional investment introduced into the existing system. In particular, understanding the costs of the Project to Support PAV system introduced by the project partners is of considerable interest to MISAU, which must ultimately bear the costs of any elements of the model that are incorporated into its own system.

The Project to Support PAV in Cabo Delgado revolved around installing a vaccine distribution system that incorporated supportive supervision and data management with the distribution of vaccines, syringes, propane, and other supplies required to provide vaccine services at a health center. This vaccine logistics system and grouping of activities was a core innovation of the project and involved changing the allocations and possibly the total amount of costs dedicated to vaccine programs. While the vaccine logistics system implemented in Cabo Delgado is different from the existing vaccine logistics systems in other provinces of Mozambique, many of its features, such as waste management infrastructure and trainings have already been incorporated into MISAU planned activities and budgets. Therefore, a study of the vaccine logistics system costs is of utmost interest to the project partners, other countries, and other stakeholders examining vaccine logistics systems to the last mile. Understanding the costs of each system is vital to policy decision-making regarding the expansion of the Project to Support PAV vaccine logistics system.

Objective

The objective of this study was to compare the costs of vaccine logistics in Cabo Delgado province, where the project operated, with similar vaccine logistics costs in Niassa province, where MISAU's regular vaccine logistics system operates. The Project to Support PAV logistics system in Cabo Delgado employed an active logistic delivery system where vaccines were reliably delivered to the health facilities each month, while Niassa's vaccine logistics system consists of a mixed and inconsistent system combining collection and distribution based activities that vary by location and month. Therefore, this comparison facilitates an understanding of the incremental costs to the vaccine logistics system used by the Project to Support PAV.

Methodology Description

This study involved data from the vaccine logistics systems in Cabo Delgado and Niassa provinces. Both sets of data were entered into an Excel-based cost model that included the portion of transport, personnel, cold chain, and vaccine and other supply costs that apply to PAV.[2] For Cabo Delgado, the actual incurred costs were entered into the model, thus the model merely added the costs. In Niassa, a sampling of data was collected in field work conducted in May 2009 at nine health centers in eight districts that were selected randomly using probability proportional to size.[3] This sampling gathered the costs for each segment in the supply chain and their portion applicable to PAV and the model then projected and calculated the costs for the entire province. The result was the total costs to operate a PAV supply chain for one year in both provinces, the total cost per child receiving DPT-Hep B3 (as a proxy for a fully immunized child), total cost per child under age five, and the total cost per vaccine dose delivered. As the costs from Niassa were based on survey data, the actual costs could vary from these projections.

This study included four primary limitations. First, Cabo Delgado and Niassa are two different provinces with different sizes, populations, and health system characteristics. However, the costs in Cabo Delgado before the Project to Support PAV system are not known and Niassa was consequently selected to serve as a comparison province. Second, the identification of costs in Niassa were particularly difficult to gather and in several instances, different survey respondents provided different costs for the same items. The result is reduced confidence in the survey responses in some cases. Third, the costs in Niassa are for vaccine distribution only, but the distribution of vaccines was combined with other items in Cabo Delgado. These other items included syringes, diluents, safety boxes, and gas for operating equipment. Finally, no incremental refrigerator maintenance costs were included for either province. In the case of Cabo Delgado, the maintenance costs were included in the logistics system costs, but respondents in Niassa reported that no refrigerator maintenance was completed due to lack of skills and funds. For a more comprehensive description of the study methodology and limitations, see *Appendix A: Detailed Methodology Description*.

Description of the Vaccine Logistics Systems Assessed

To understand the cost bearing activities in the vaccine logistics systems, it is important to understand how the systems are structured and operate. This section describes the systems in both provinces included in the study.

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[2] Although the model accommodates cold chain depreciation costs, these costs were excluded from the main section of this report because the cold chain infrastructure in the two provinces is vastly different. To see how the cold chain depreciation alters the study results, see *Appendix D: System Costs Including Cold Chain Depreciation*.

[3] Four of the ten health centers selected with the random sampling were replaced with different facilities for reasons including inaccessibility due to weather conditions, closed vaccine services, or serving as a district warehouse. A fifth health center was not included because it had not been operating vaccine services due to a broken refrigerator. This essentially transformed the sample into a purposive, rather than random, sample. See *Appendix A: Detailed Methodology Description* for more information.

In addition to differences in the vaccine logistics systems, Cabo Delgado and Niassa have demographic differences, albeit similar rural and economic conditions. With a population of 1,178,117 Niassa has a significantly lower population than Cabo Delgado, which has 1,632,809 residents. The two provinces also differ in size as Niassa is 129,050 km^2 and Cabo Delgado is 77,867 km^2. Consequently, Niassa's population density is 9 people per square kilometer whereas Cabo Delgado has 21 inhabitants per square kilometer. Despite these demographic differences, the two provinces have very similar GDP per capita, life expectancies, literacy rates, and mortality rates. However, Niassa stands out for the percentage of births taking place in a health facility, which is 75% compared to only 40% in Cabo Delgado.[4]

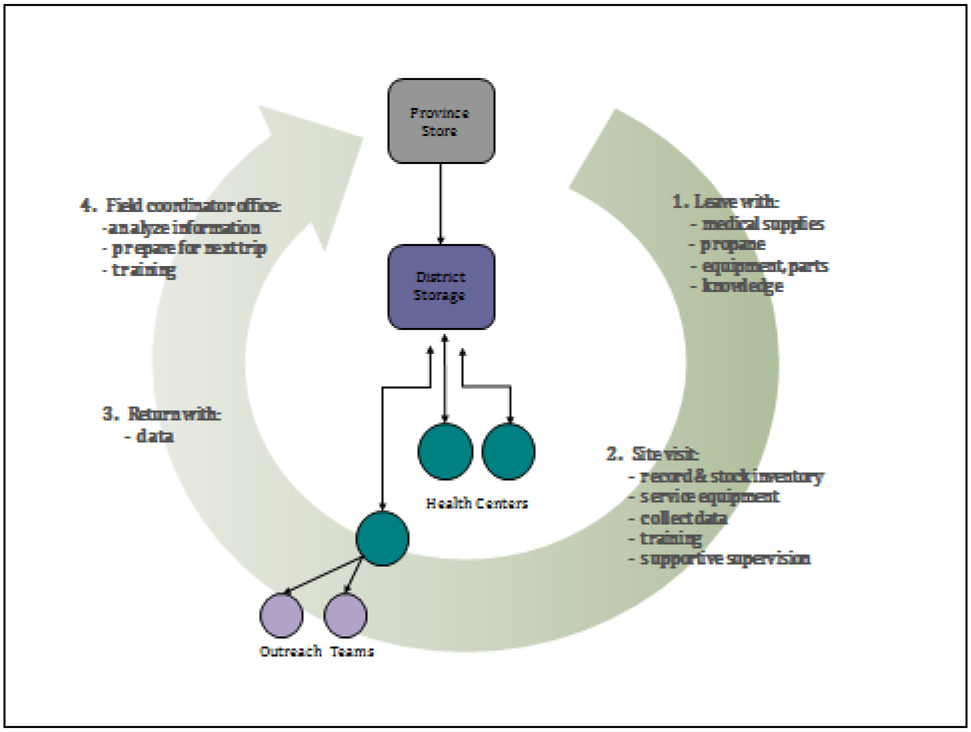
The Project to Support PAV System in Cabo Delgado Province

The Project to Support PAV established a functional team comprised of field coordinators who performed various distribution and support activities for health centers. During the project, implementing partners MISAU, FDC, and VillageReach hired, trained, and managed three field coordinators and drivers. The field coordinators and drivers formed a functional team and the purpose and activities performed by the functional teams are illustrated in the diagram below. Each field coordinator was responsible for a group of health centers and related outreach teams, generally 30-40 health centers in 5-6 districts. A field coordinator visited each health center for which he was responsible on a monthly schedule.[5] At the beginning of each month, he left his office with the items identified in group 1. The medical supplies included vaccines, syringes, safety boxes, diluents, and other items as appropriate. At each health center, he performed a site visit covering activities identified in group 2. During the site visit, he confirmed that basic maintenance of cold chain equipment was properly conducted and if not, then he worked with the health center staff to perform the maintenance activities. Upon returning to his office with data collected during the site visit, the field coordinator performed the tasks in group 4.

[4] All statistics from "Indicadores Sociais, Económicos e Populacionais ao Nível do Distrito, Fundação para o Desenvolvimento da Comunidade, Maputo, 2007".

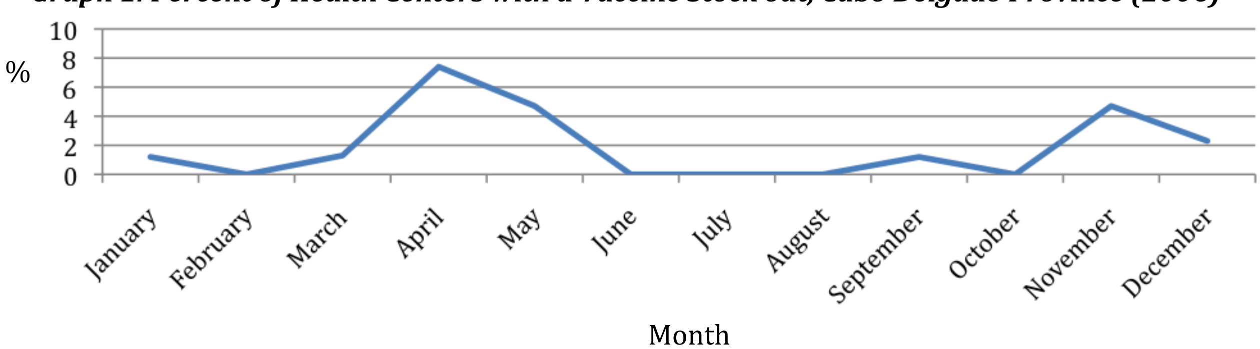
[5] Although women are not excluded from becoming field coordinators, this report refers to field coordinators as "he". To date, only one of seven field coordinators has been female.

Diagram 1: Cabo Delgado Vaccine Logistics System with the Project to Support PAV



Cabo Delgado province had 88 fixed vaccination posts at the time of data collection in 2006. Because of the design of the logistics system, all of the routine vaccine transport was conducted with trucks (open cab Toyota Land Cruisers) and was done on a distribution-based system. Of the 88 health centers 80 had gas-powered refrigerators and eight had solar powered refrigerators. During the year of the data collection, there were nine refrigerator breakdowns. Seven of the refrigerator problems occurred with the gas refrigerators and the remaining two in the solar refrigerators. A vaccine stock out occurs when a health center has no stock of any one vaccine that they are expected to administer. The graph below shows the stock outs in the province during the year.

Graph 1: Percent of Health Centers with a Vaccine Stock out, Cabo Delgado Province (2006)



Mapping Niassa's Vaccine Logistics System

The survey in Niassa revealed the vaccine supply chain to the sample health centers varied by district and by month. There was no routine system to distribute vaccines and in some cases the vaccines were collected from the province and/or district, while in others they were distributed from the districts to the health centers. The province has a regional vaccine store in Cuamba that serves four of the districts included in the sample. The regional store staff and DPS (Direcção Provincial de Saúde / Provincial Department of Health) reported that the process for stocking the facility is done quarterly, but who performs the distribution and how it is done varies each quarter.

The diagram below shows directional trips for vaccine distribution. For each vaccine distribution segment, the survey gathered three months of data, except in the case of three districts and three health centers where recall was not sufficient. The arrows in the diagram indicate the flow of vaccines for each month. For example, the district health workers of Mandimba traveled to the province once a month during the survey period (February, March, and April 2009). In the same three months, Lipusia health center staff traveled twice to Mandimba to pick up vaccines and once the Mandimba district staff came to the health center to distribute vaccines.

Diagram 2: Mapping Niassa Vaccine Distribution (2009)

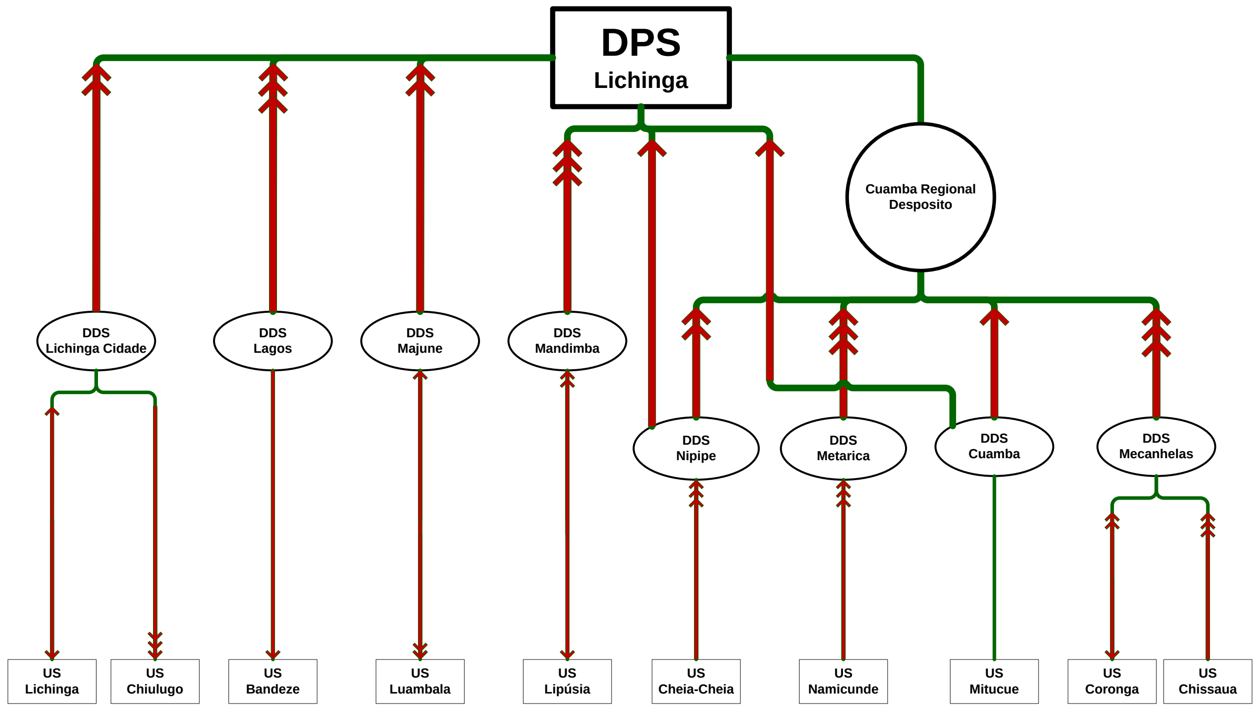


Diagram Key	
DPS	Direcção Provincial de Saúde / Provincial Department of Health
DDS	Direcção Distrital de Saúde / District Department of Health
US	Unidade Sanitária / Health Unit
Cuamba Regional Deposito	Regional Store in Cuamba
Arrow Segments	Directional trip for vaccine distribution in one month

DPS Niassa reported having a total of 89 vehicles and 90 motorcycles. At the time of the survey in May 2009, 59 of the vehicles were functioning and 20 of the broken vehicles were irreparable. In the first quarter of 2009, 1/3 of the motorcycles in the province had broken down. The duration of vehicle and motorcycle breakdowns varies greatly. Some reported breakdowns lasting for only a day and the longest citation was two years. The frequency of breakdowns also varied greatly ranging from "rare" to "constant." DPS and several districts reported many problems with reliable transport, primarily around accessing the funds for fuel and per diems.

Over the three-month period, the field work captured the flow and costs for 46 transport segments. One *transport segment* represents a one-way transport of vaccines from point A to point B. The table below shows these segments by transport type and disaggregated to district and health unit. As can be seen below, the modes of transport vary from truck and ambulance to motorcycle, chapa (bus), bicycle, and foot.

Table 1: Niassa Transport Segments by Transport Type and Health System Level

Total number of district trip segments: 22			**Total number of health unit trip segments:** 24		
Different Types of Transport			**Different Types of Transport**		
	Number	Percentage		Number	Percentage
Truck	15	68%	Truck	7	29%
Ambulance	6	27%	Ambulance	0	0%
Motorcycle	0	0%	Motorcycle	8	33%
Chapa	0	0%	Chapa	3	13%
Bicycle	0	0%	Bicycle	4	17%
Foot	1	5%	Foot	2	8%

Several districts reported that stock outs of vaccines were common and one reported that health units often go weeks with stock outs and only report it when they bring in their requisitions for the next month's vaccines. The field work found 15 stock outs of at least one type of vaccine from the total 46 transport segments included in the survey. That represents a 33% stock out rate in the province.

Of the ten health centers surveyed, seven used solar refrigerators, three used kerosene, and two used electric. Of these, two of the solar refrigerators were broken. Each of the eight districts reported the cold chain status of the health centers in their catchment, which is shown in the table below.

Table 2: Status of Refrigerator Operation in Niassa Sample Districts

Refrigerator Type	**Total**	**Working (%)**	**Not Working (%)**
Solar	32	24 (75%)	8 (25%)
Kerosene	24	20 (83%)	4 (17%)
Electric	12	10 (83%)	2 (17%)
Total	**68**	**54**	**14**

III. Results

Comparison of Project to Support PAV Costs in Cabo Delgado and Niassa Costs

This study found that the absolute cost to operate a vaccine logistics system for one year is higher in Cabo Delgado province, but the costs controlling for population differences is less in Cabo Delgado province. The study also found that the vaccine logistics system in Cabo Delgado province is more cost-effective and efficient. The table below summarizes the two province basic vaccine-related characteristics and logistics system costs by highlighting four comparisons: absolute cost, cost controlling for population differences, relative cost-effectiveness and relative cost-efficiency.[6]

[6] In this study, cost-effectiveness is the increase in health outcome (measured by childhood vaccination) relative to the expenditure. Cost-efficiency measures the effort (measured by doses delivered) relative to the expenditure.

Table 3: Summary of Niassa and Cabo Delgado Vaccine Characteristics and Logistics System Costs

Characteristic / Comparison	**Niassa**	**Cabo Delgado**	**Difference**
Absolute Costs			
Population	1,178,117	1,632,809	-454,692
Total Vaccine Logistics Costs for 1 Year	$266,563.04	$305,418.80	-$38,855.76
Transport	*$ 35,968.39 (14%)*	*$ 55,234.48 (18%)*	*-$19,266.09 (-4%)*
Personnel	*$75,482.23 (28%)*	*$ 35,376.00 (12%)*	*+$40,106.23 (16%)*
Cold Chain	*$31,306.42 (12%)*	*$27.191.82 (9%)*	*+$4,114.60 (3%)*
Vaccines & Supplies	*$123,806.00 (46%)*	*$187,616.51 (61%)*	*-$63,810.51 (15%)*
Costs Controlling for Population Differences			
Population of Children Under 5 Years	179,892	303,007	-123,115
Total Cost Per Child Under 5 in 1 Year	$1.48	$1.08	$0.40
Relative Cost-Effectiveness			
DPT3 2008 Coverage Rate among children aged 24-35 months[7]	70%	95.4%	-25.4%
Total Cost Per Child Receiving DPT-Hep B3 in 1 Year	$6.07	$5.03	$1.04
Relative Cost-Efficiency			
Number of Vaccine Doses Delivered in 1 Year	498,624	889,152	-390,528
Total Cost Per Dose of Vaccine Delivered[8]	$1.50	$1.18	$0.32

[7] See *Evaluation of the Project to Support PAV (Expanded Program on Immunization) In Northern Mozambique, 2001-2008: An Independent Review for VillageReach with Program and Policy Recommendations* for details of the coverage rates.

[8] The total cost per dose of vaccine delivered is calculated by totaling the transport, personnel, and cold chain costs and dividing by the total doses delivered. Then because the vaccines and syringes have a cost per dose, those costs are added to the result.

As shown in the table above, the total costs to operate the vaccine logistics system for one year was $38,855 greater in Cabo Delgado then in Niassa. The biggest difference in costs is in the cost of vaccines, which is $63,810.51 higher in Cabo Delgado and is reflected in the higher vaccine coverage rate in the province. Niassa was also less expensive in transport, but more expensive for personnel and cold chain maintenance costs. While the system in both provinces invests the largest proportion of resources in the vaccines and supplies, the proportion is significantly higher in Cabo Delgado than in Niassa, indicating relative efficiency. For details of the results in both provinces, see *Appendix B: Analysis of Results for Cabo Delgado* and *Appendix C: Analysis of Results for Niassa Costs*.

The table above also shows that Niassa's population is 28% less than the population of Cabo Delgado. To control for the population differences, we calculated the costs per child under age 5, which is $0.40, or 27%, higher in Niassa. This comparison indicates a higher level of effort to manage vaccine logistics in Niassa than in Cabo Delgado.[9]

The third calculation and comparison in the table above, cost per child receiving DPT-Hep B3, indicates the relative cost-effectiveness of the two vaccine logistics systems. This cost is $1.04 higher in Niassa than in Cabo Delgado. This difference calculates to 17% greater costs to operate the diffused vaccine logistics system in Niassa than the dedicated system used by the Project to Support PAV in Cabo Delgado.[10]

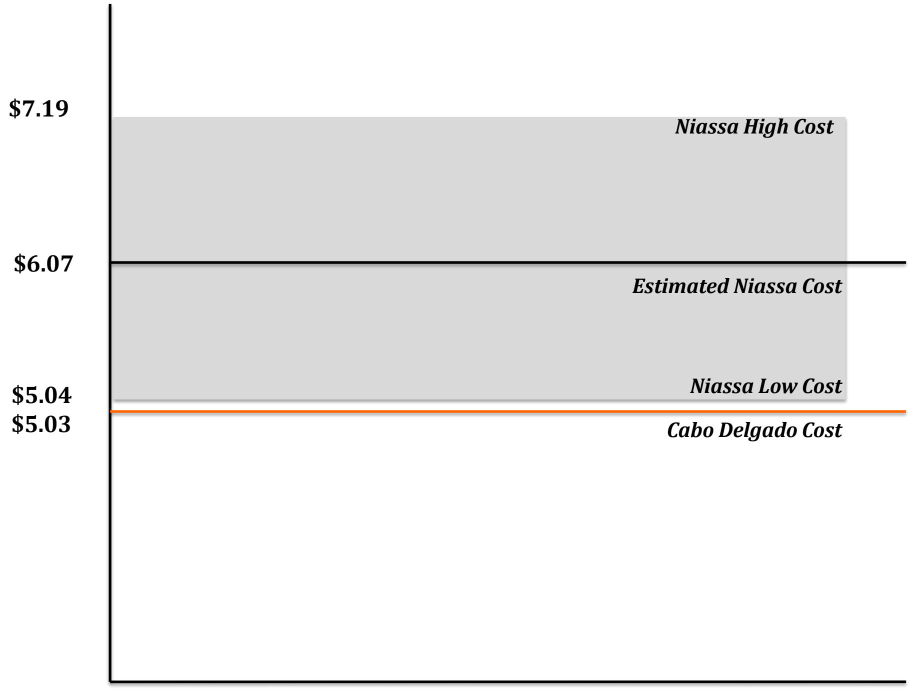
The final section of the table above examines the relative cost-efficiency of the two vaccine logistics systems. By calculating the costs per dose of vaccine delivered, we uncover the financial investment and recurrent costs needed to operate the vaccine logistics systems. In Niassa province, the vaccine logistics system delivered 390,528 fewer vaccine doses than in Niassa at an additional cost of $0.32 per vaccine dose. This means Cabo Delgado is 21% less expensive per vaccine dose delivered than Niassa.

The following two graphs show the cost outputs of the two provinces in comparison to each other. The field work in Niassa found a vaccine logistics system with great variability in activities and costs. Due to this variability and because costs were pieced together based on the respondents recall of costs for the cost-bearing activities in the vaccine logistics system, this study produced a range of costs for Niassa. The graph below shows this range of costs and how it compares to the estimated costs in Niassa as well as the cost in Cabo Delgado.

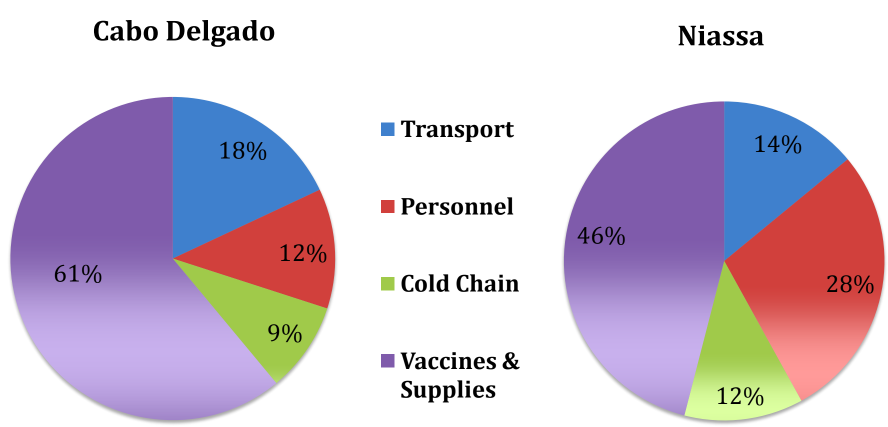
[9] However, vaccine logistics system costs have fixed and variable costs and Niassa's lower population and larger geographic size mean that even with maximum efficiency, Niassa's costs per child under age 5 will always be higher than in Cabo Delgado. For more details and analysis on this issue, see *Section V. Costs of Implementing the Project to Support PAV System in Niassa*.

[10] Similar to the cost per child under 5, this cost will always be greater in Niassa even with maximum efficiency. This issue is discussed in more detail in *Section V. Costs of Implementing the Project to Support PAV System in Niassa.*

Graph 2: Cabo Delgado and Niassa Vaccine Logistics Costs per Child Vaccinated with DPT-Hep B3 for 1 Year with Niassa High and Low Ranges



Graph 3: Percentage Breakdowns of Vaccine Logistics Costs for One Year in Cabo Delgado and Niassa Provinces



Comparison of Transport Costs

The absolute transport costs for one year of vaccine logistics were $19,266.09 higher in Cabo Delgado province than in Niassa province. This is accounted for by two factors. First, all vaccine logistics in the Cabo Delgado costs were completed using vehicles, while 21.7% of the transport segments were completed with less expensive chapa (bus) or free non-motorized transport. Second, in Cabo Delgado province three vehicles were allocated 100% to vaccine logistics while in

Niassa the vehicles were shared. Due to the differing coverage rates in the two provinces, the transport costs per child vaccinated with DPT-Hep B3 is $0.09 higher in Cabo Delgado province, while the cost per vaccine dose delivered is $0.01 higher in Niassa. Similarly, the transport costs as a percentage of overall vaccine logistics costs are higher in Cabo Delgado at 18% versus 14% in Niassa.

Comparison of Personnel Costs

The overall personnel costs to operate the vaccine logistics system for one year were $40,106.23 higher in Niassa province than in Cabo Delgado. This increase is due entirely to the higher cost of per diems, which was $47,416.92 higher in Niassa than Cabo Delgado for one year. A larger number of people and days were used in Niassa to manage vaccine logistics and a lower per diem rate was negotiated for the field teams managing vaccine logistics in Cabo Delgado. However, the personnel salaries are $7,310.68 higher per year in Cabo Delgado province because 100% of the time of six staff was applied to the vaccine logistics costs, whereas only a portion of various staff time was allocated in Niassa province.

The total personnel costs are $1.14 higher per each child vaccinated with DPT-Hep B3 and $0.11 more per vaccine dose delivered over one year in Niassa province. This is due to the higher coverage rate in Cabo Delgado that was brought about in part from improved logistics, supervision, and information management activities experienced as a result of the Project to Support PAV field team work. Similarly, the personnel costs total 28% of the total vaccination logistics costs in Niassa versus 12% of total vaccine logistics costs in Cabo Delgado.

Comparison of Cold Chain Costs

Cold chain costs over one year are $4,114.60 higher in Niassa province over Cabo Delgado province. This increase is accounted for by refrigerator repairs, which is $16,058.48 higher for one year in Niassa. Repair costs are higher in Niassa for three reasons. First, 80 of the 88 refrigerators in Cabo Delgado were new refrigerators provided 2-4 years before the data collection period in 2006. Second, as revealed in the field work, little to no refrigerator maintenance was completed in Niassa province due to lack of capacity in the health centers. In Cabo Delgado province, the field coordinators supervised and performed refrigerator maintenance activities during the vaccine distribution visits and the increased maintenance resulted in fewer breakdowns. Similarly, most of the refrigerator repairs in 2006 in Cabo Delgado province were simple breakdowns, which were fixed by the field coordinators during the vaccine distribution visits. As such, those repairs bore only the additional cost of spare parts.

Despite the lower refrigerator repair costs in Cabo Delgado province, the fuel costs for one year were $11,943.79 higher in Cabo Delgado over Niassa. This is also accounted for by the high number of solar refrigerators in Niassa province, which do not have recurring energy costs.[11]

As a percentage of the total vaccine logistics system costs, cold chain costs were slightly higher in Niassa than Cabo Delgado at 12% and 9% respectively. As expected, the cold chain cost per child vaccinated with DPT-Hep B3 is $0.26 higher in Niassa than Cabo Delgado. Similarly, the cost per vaccine dose delivered is $0.03 higher in Niassa.

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[11] Although solar refrigerators do not have recurring energy costs, they do require a higher initial investment. See *Appendix D: System Costs Including Cold Chain Depreciation* for analysis of the costs that includes the varying cold chain investment costs in the two provinces.

Comparison of Vaccine and Supplies Costs

The procurement price of vaccines and syringes used for each province was the same. However, Cabo Delgado spent $63,810.51 more on vaccines and syringes than Niassa province due to a higher number of children vaccinated and higher wastage rates in Niassa. The wastage factors for Cabo Delgado were based on actual open and closed vial wastage rates incurred in 2006, which were available because they were tracked by the Project to Support PAV. However, the existing Ministry of Health information system does not record incurred wastage rates. Therefore, we calculated the wastage factors based on the national wastage rates the Ministry of Health uses for vaccine and supply forecasting. The table below shows the different wastage factors used in this study.

Table 4: Wastage Factors Used for Niassa and Cabo Delgado

Vaccine	Wastage Factor[12]	
	Niassa	Cabo Delgado
BCG	2.00	1.42
DPT-Hep B	1.18	1.06
Polio	1.18	1.09
Measles	1.67	1.25
Tetanus	1.18	1.06

In Cabo Delgado, the 61% of the vaccine logistics system costs were the vaccines and supplies, versus 46% in Niassa. As such, the commodity being managed by the system was a larger portion of the cost in Cabo Delgado than in Niassa where personnel made up a larger portion of total costs.

Description and Analysis of Costs Not Quantified

While the costing model is not able to quantify further gains in health system efficacy enabled by the Project to Support PAV in Cabo Delgado such as the opportunity costs of unstaffed health unit days or catastrophic equipment failures, it can be assumed that there are further health system benefits from increased health worker productivity. If a health worker is picking up vaccines, then they are not providing healthcare. Similarly, if a piece of equipment breaks and cannot be repaired or is deemed cost-inefficient to repair, then the equipment is no longer used. If the equipment is not replaced, then vaccine services are interrupted. These costs are not quantified in this study. However, they are accounted for in the number of children vaccinated with DPT-Hep B3, as the number in Niassa has a lower coverage than in Cabo Delgado.

Non-Cost Advantages of Implementing the Project to Support PAV Logistics System

This report has analyzed the cost implications of the Project to Support PAV vaccine logistics system. While the costs of implementing the system have serious implications on policy making, the other advantages of the system must be considered. As has been documented in the Project to

[12] Wastage factor is 100/ (100-Wastage Rate) as used by the World Health Organization. Details on this factor can be found at http://www.who.int/immunization_delivery/vaccine_management_logistics/logistics/expected_wastage/en/index.html.

Support PAV evaluation[13], the system increases vaccination coverage rates. During the project in Cabo Delgado, coverage rates of DPT-Hep B3 increased from 68.9% to 95.4%. In addition, all other vaccines had similar increases resulting in a 92.8% coverage rate for all childhood vaccinations. This increase is accounted for in this study as the cost per child vaccinated with DPT-Hep B3 and the cost per vaccine dose delivered. Additional advantages of the Project to Support PAV logistics system include:

- Increased supervision at the health units.
- Improved data collection and analysis at health units.
- Increased availability of vaccine service and logistics information at all levels of the system.
- Reduction of vaccine stock outs. During the project in Cabo Delgado stock outs reduced from 80% to less than 1%.
- Improved cold chain maintenance and operation.
- Decreased vaccination dropout rates. During the project in Cabo Delgado, dropout rates between DPT-Hep B1 and DPT-Hep B3 decreased from 12% to as low as 3.8%.
- Improved quality of vaccination services and access to vaccines.
- Increased knowledge of, trust in, and use of the public health system.

IV. Conclusions

Several conclusions can be drawn from this cost study. With a detailed understanding of the costs of vaccine logistics in Cabo Delgado with the Project to Support PAV system and Niassa including the cost inputs, variable factors that affect costs, total costs for a province, cost per child vaccinated with DPT-Hep B3, and cost per vaccine dose delivered, we conclude the following:

- The Project to Support PAV system results increased vaccination coverage rates, thereby bringing improvements in cost-effectiveness and cost-efficiency. This ultimately introduces cost savings into the government systems.
- To achieve the cost savings that were realized in Cabo Delgado with the Project to Support PAV system, MISAU and DPS must make initial additional investments to establish the system. Investment in transport is required for the system. Additional investment in new cold chain equipment and health worker training in cold chain maintenance can result in increased cost efficiencies. Such investments can be subsidized with the reduction in per diem costs and decreased refrigerator breakdowns.
- Additional cost savings could be realized with the Project to Support PAV system if the logistics activities are integrated with other areas of health. For example, the vaccine distribution, supervision, and information management activities could be combined with nutrition or malaria programs. Such integration would result in savings particularly in personnel and transport costs.

[13] See *Evaluation of the Project to Support PAV (Expanded Program on Immunization) In Northern Mozambique, 2001-2008: An Independent Review for VillageReach with Program and Policy Recommendations* for details of the coverage rates.

V. Costs of Implementing the Project to Support PAV System in Niassa

With a detailed understanding of the Project to Support PAV system costs and the existing vaccine logistics costs in Niassa, it is possible to predict the costs of implementing the Project to Support PAV system in Niassa. Niassa's larger geographic size and smaller population impact the costs in the province. Niassa is 129,050 km^2 with a population of 1,178,117 and a population density of 9 inhabitants/km^2. Cabo Delgado is 77,867 km^2 with a population of 1,632,809, which translates to 21 inhabitants/km^2. Despite these differences, economic and health indicators in the two provinces are very similar with one exception: over 75% of births in Niassa take place in a health facility versus only 40% in Cabo Delgado. While no private health system exists throughout Cabo Delgado, Niassa has 79 privately-operated health facilities managed by a faith based organization.

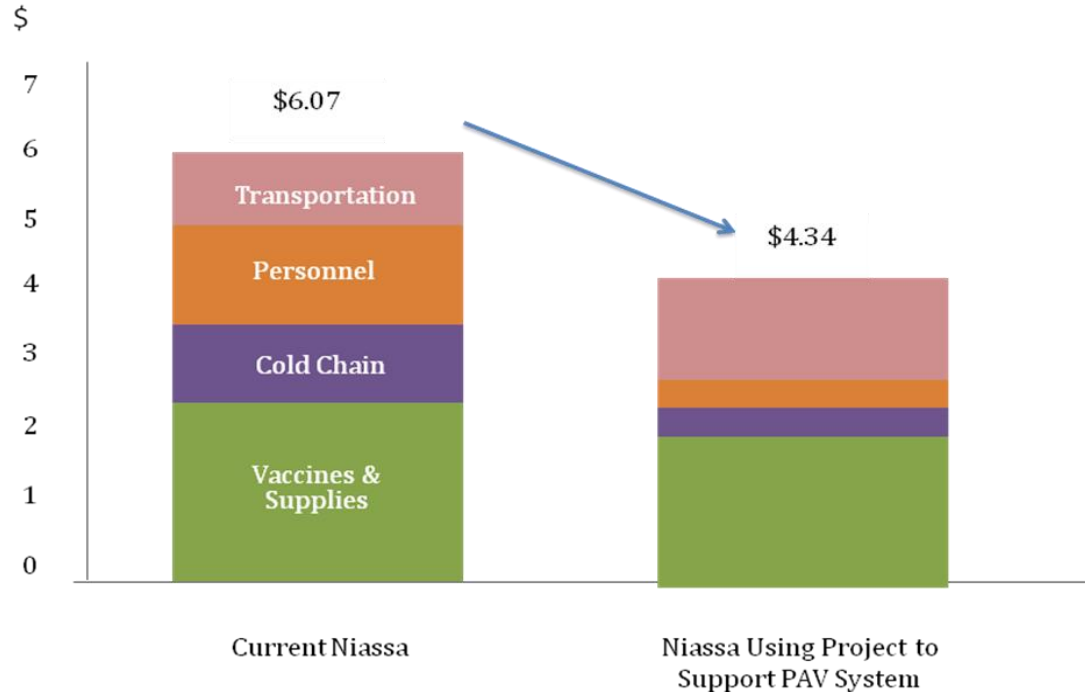
These differences in the two provinces have implications on expanding the Project to Support PAV vaccine logistics system to Niassa. First, as a result of the size and population differences, the number of children vaccinated will be lower in Niassa and therefore the cost per child vaccinated with DPT-Hep B3 and the cost per vaccine dose delivered will always be higher in Niassa than in Cabo Delgado. Second, the system will need to cover more area resulting in higher transport costs. Third, the use of health facilities is higher in Niassa than in Cabo Delgado, as evidenced by the rate of births taking place in health facilities. This indicates that achieving a higher coverage rate in Niassa should be facilitated by the high use of health facilities making it relatively easier to achieve than in Cabo Delgado.

Using the cost model and adjusting for the differences in population and geographic size, we predict a total annual cost to implement the Project to Support PAV system in Niassa of $251,883 for a total cost per child receiving DPT-Hep B3 of $4.34 and a cost per vaccine dose delivered of $1.24. This represents an annual savings of $14,680 from the current vaccine logistics system in Niassa, a reduction of $1.73 per child vaccinated with DPT-Hep B3, and a $0.26 decrease in the cost per vaccine dose delivered. This modeled cost is based on the following:

- Achieving a 20% coverage rate increase for all vaccines;
- Achieving the wastage rate levels met in Cabo Delgado with the Project to Support PAV logistics system;
- A 25% reduction in refrigerator breakdowns while using the existing cold chain;
- Using three field coordinators and three drivers to operate the system at the existing MISAU salary level currently given to field coordinators hired by DPS in Nampula and the average driver salary from the field work done by this study in Niassa; and
- The per diem rate used in Cabo Delgado and Nampula by the Project to Support PAV.

The details of this cost prediction are provided in *Appendix E: Estimated Niassa Costs with the Project to Support PAV System*. The graph below shows the costs savings of implementing the Project to Support PAV system in Niassa.

Graph 4: Cost Savings from Implementing the Project to Support PAV in Niassa per Child Vaccinated with DPT-Hep B3



Additional Investment Required for Niassa

Implementing the Project to Support PAV system in Niassa requires additional investment in vehicles and staff. Specifically, three open cab Toyota Land Cruisers need to be purchased and three drivers and field coordinators need to be allocated to these positions. From the costs incurred in Cabo Delgado, the investment in additional vehicles requires $113,975.40.

Achieving Breakeven on the Investment

For the investment in vehicles to produce sufficient financial gains for MISAU, the cost savings of the cash expenses of running the logistics system must be greater than cost of the vehicles. To determine the cash expenses of running the logistics system, we removed all depreciation expenses. Once the cost of the vehicle investment is greater than the difference in cost savings, then MISAU has achieved a breakeven point on the investment. The calculation below shows the difference in cash expenses compared to the vehicle investment.

Current Niassa Vaccine Logistics System Cash Expenses for 1 Year	$266,563
Predicted Niassa Project to Support PAV Cash Expenses for 1 Year	- $229,087
Difference	$37,476
Cost of Vehicle Investment	$113,975.40

From these figures, after 3 years the savings from implementing the Project to Support PAV system is equal to the investment required. As the vehicle life in northern Mozambique is approximately five years, the vehicle investment results in savings much greater than the cost throughout the life of the vehicles.

Achieving Increased Productivity with the Investment

Investing in the vehicles to implement the Project to Support PAV system in Niassa will also result in an increase in health worker productivity in the province. The field work in Niassa found that every month in the sample, 21 staff used 32 days on vaccine logistics. Modeled for the entire province, that represents 348 staff days throughout the province for one month. In the Project to Support PAV system, these staff would be attending to their health service provision duties instead of distributing vaccines. In the Project to Support PAV logistics system, the dedicated staff use a total of 132 days per month on vaccine logistics, which is six staff with 100% of their time allocated to vaccine logistics. Therefore, investing in vehicles for the Project to Support PAV system frees up 216 days of staff time per month, which allows for incremental improvements in health worker productivity by removing unproductive days of health worker time spent on vaccine logistics.

Conclusion

In conclusion, while implementing the Project to Support PAV system in Niassa will result in decreased overall PAV costs, it requires an increase in MISAU costs, by requiring an initial investment in vehicles to operate the system. As a result of the investment and the implementation of the Project to Support PAV system, the province will experience an increase in coverage rates, which decreases cost per dose and fully immunized child in the province. Simultaneously, the system will increase the overall performance of the system by increasing the productivity of health workers, resulting in better health provision and improved health impacts in the province. Ultimately, the initial investment to implement the Project to Support PAV system in Niassa will result in cost savings for MISAU.

Appendix A: Detailed Methodology Description

To understand the incremental costs of vaccine logistics with the change in distribution system introduced in the Project to Support PAV system, it was necessary to compare the costs in Cabo Delgado province with a control province. In this study, Niassa province served as a control province. Niassa was selected due to the similar rural conditions and challenging logistics environment. Despite having similar numbers of health facilities, districts, and economic and health indicators, Niassa has a significantly lower population and lower population density than Cabo Delgado. The table below highlights some basic demographic and health indicators in Cabo Delgado and Niassa provinces.[14]

Table 5: Comparison of Niassa and Cabo Delgado Provinces

Indicator	Niassa	Cabo Delgado
Fixed Vaccination Posts	98	89
Districts	16	17
Population	1,178,117	1,632,809
Size	129,050 km^2	77,867 km^2
Population Density	9 inhabitants per km^2	21 inhabitants per km^2
Life Expectancy	44.7 years	41.9 years
GDP per capita	$87	$82
Percent Literate	35%	23%
Average Number of Children Born Per Woman	7.2	5.9
Percent of Births Taking Place in a Health Facility	75.4%	40%
Number of Hospital Beds per 1,000 population	0.7	0.6
Maternal Mortality Rate	0.2%	0.3%
Infant Mortality Rate	18.4%	17.8%

While in Cabo Delgado the relevant costs are known and easily accessible from project accounting records, many of these same costs are unknown in Niassa province and therefore, it was necessary to create a systematized model to estimate the costs incurred in Niassa. To determine the vaccine logistics system costs of supporting rural vaccine centers, industrial engineers from the University of Washington developed an Excel-based tool to calculate costs, referred to as the *cost model* in this study. The tool was developed with input from VillageReach and refined and validated by a PATH health economist. Because MISAU's vaccine-specific logistics costs are not available, the tool was designed to model these costs under various distribution scenarios that replicate and estimate the costs of supporting rural vaccine centers by supplying vaccines, and maintaining and repairing equipment, such as refrigerators and vehicles, used in support of PAV. The model was designed to accommodate a full data set of costs for all health centers in a province or a full data set for a sampling of health centers to represent the costs for the entire province. In the latter case, the cost model factors the costs to determine a full cost for the entire province. Specifically, for this study, in

[14] All statistics from "Indicadores Sociais, Económicos e Populacionais ao Nível do Distrito, Fundação para o Desenvolvimento da Comunidade, Maputo, 2007".

Cabo Delgado province the costs for all health centers were included, whereas in Niassa province a sample of health care centers (nine health centers out of a total of 98) was used to estimate total costs for Niassa province.

Cost Definitions

Costs included in the model projections included those related to supporting vaccine services at rural vaccine centers. These costs included:

- Vaccines and syringes, including a wastage factor
- Personnel costs
  - Salaries of health and administrative staff to distribute vaccines
  - Per diems for health and administrative staff to distribute vaccines
- Transport costs
  - Vehicle depreciation
  - Vehicle insurance costs
  - Fuel
  - Vehicle maintenance including labor and parts
  - Vehicle breakdown repairs including the labor, parts, and per diem for traveling time for breakdowns that require transport to Nampula (a large, hub city where the most complicated repairs are completed). It does not include the cost of using a vehicle or fuel for transport or transporting broken vehicles within the province.
  - Public transport usage costs
- Cold chain costs
  - Cost of fuel to power the refrigerator
  - Refrigerator maintenance costs. While the model includes maintenance activities, both provinces reported no costs for maintenance. Cold chain maintenance is not carried out in Niassa due to budget restrictions and limited basic mechanical knowledge in the health units. In Cabo Delgado, refrigerator maintenance was done in the health center at the same time of the vaccine distribution, the costs of which are included in the vaccine distribution activities.
  - Refrigerator repair costs. This includes the cost of labor, per diems, and parts for repairs. The cost of transport for mechanics to get to the broken refrigerators is not included in these costs.

Cost Measurement

Only costs directly related to PAV logistical support were measured. For example, if a Preventative Medicine Technician spends two days in a month picking up vaccines and supplies, only that percent (2 days / total 22 working days in a month) of his or her salary is included in final costs. If the technician's trip was only half for vaccine distribution, then only half of the percentage of his or her salary was included. The same principle was applied to all cost-bearing activities.

Source Data

Two data sets were used for this study.

1. VillageReach used 2006 data from project accounting records in Cabo Delgado to determine the costs of vaccine logistical support using the project system. These costs were

supplemented with cold chain data gathered in Cabo Delgado, as refrigerator repair costs were not included in the project accounting records.

2. Survey data. In May 2009, data was collected from the neighboring province of Niassa, which has similar development indicators and challenging rural conditions as Cabo Delgado province. The field work collected data for the vaccine distribution in February, March, and April 2009.

Niassa Sample Selection

Independent consultants collected distribution data based from a sample of 10 health centers in Niassa province to represent the costs of the system used throughout Niassa. The centers, which account for 10% of all fixed vaccination posts in the province, were randomly selected to represent the various health center and logistic conditions in the province. The random selection was based on probability proportional to size using the catchment population of each health facility per the 2007 census data and obtained from DPS Niassa. The field work traced the distribution of vaccines at the health unit and districts as the vaccines traveled through the health system.

Once the field work began, for various reasons, five of the ten randomly selected health centers chosen for field work were eliminated from the study and four were changed to the geographically closest health center. For example, in the Lagos district, Bandeze health center was substituted for Metangula health center because Bandeze also served as a vaccine storage point so it did not accurately fit the profile of the average health center. In the Metarica district, the Metarica health center was replaced by Namicunde for the same reason. In Mecanhelas, the original health center selected was new and had never provided vaccine services and so it was replaced with Chissaua health center. In the Nippe district, the original clinic selected was inaccessible because of a flooded road, thus Caronga health center was substituted. In Mecanhelas the original selection was replaced by Chissaua health center also due to a flooded road. Mitucue health unit in Cumba district was not able to provide any data for the study because their refrigerator had broken and they did not offer vaccine services during the months included in the study. Replacing four of the ten health centers in the sample essentially resulted in a purposive sample, rather than the originally designed random sample. The health units included in the study using this methodology are listed below.

Niassa Districts and Health Units Included in the Sample

District	Health Unit
Cuamba	Mitucue
Lagos	Bandeze
Lichinga City	Lichinga
Lichinga City	Chiulugo
Majune	Luambala
Mandimba	Lipúsia
Metarica	Namicunde
Nippe	Cheia-Cheia
Mecanhelas	Caronga
Mecanhelas	Chissaua

Study Population

A total of 42 surveys were conducted in Niassa among three populations:

1. PAV staff at nine health units. The interviewers spoke to the person responsible for immunization services and asked the staff about how their health facility was stocked

with vaccines for the months of February, March, and April 2009. The questions targeted details of the logistics system in order to assign costs to the various components.

2. PAV staff at eight districts. The interviewers spoke to the person responsible for immunization services and the staff was surveyed to gather information about how they stock their health facility and those in their district with vaccines. Similar to the health unit questionnaire, the questions targeted details of the logistics system in order to assign costs to the various components.

3. Province and district transport and maintenance staff. The study involved questions about the costs and cost-bearing activities related to PAV logistics transport and cold chain needs. One province level and seven district level surveys were conducted. Due to the centralized nature of cold chain management and repairs, a central level survey was also administered to fill in the gaps left by the province and district level surveys.

Limitations and Assumptions

The following limitations and assumptions were included in the study:

- Cabo Delgado and Niassa are two different provinces with different sizes, populations, and health system characteristics. However, the costs in Cabo Delgado before the Project to Support PAV system are not known and Niassa was consequently selected to serve as a comparison province.
- While the Project to Support PAV in Cabo Delgado distributed vaccines along with syringes, safety boxes, diluents and refrigerator fuel and tracked these costs respectively, the data gathered in Niassa only represented the costs of *vaccine logistics*. Because MISAU maintained independent systems and records for the costs of syringes and fuel, it was not possible to identify all costs with a reasonable level of confidence in the results during the field work.
- No refrigerator maintenance costs were included for either province. In Cabo Delgado, maintenance was carried out by health workers under the technical guidance and supervision of field coordinators at the time of vaccine delivery. In Niassa, DPS and district maintenance departments reported that refrigerator maintenance was not carried out because health workers do not have the knowledge and skills to perform maintenance and the departments do not have the budgets to perform maintenance activities.
- An exchange rate of 25 MZN per $1 USD was used for the study.
- Use of Averaging in the Niassa data: As a general rule, when respondents gave a range of costs or time for a specific item or activity, the mean amount was used. Similarly, when different respondents gave different responses for the same costs, an average cost was used in the model. For example, this applied to the number of days for a trip segment to travel to a higher level facility to pick up vaccines, salaries for the same position for maintenance, cost of spare parts, vehicle maintenance and repair costs, fuel efficiency, and frequency of breakdowns.
- Three months of data was used for each district and health center, except in the case of six transport segments. In five of the cases, recall was not sufficient to include the data and in one case, the health center did not restock vaccines during one of the months.

Appendix B: Analysis of Results for Cabo Delgado

Calculating the total costs incurred in Cabo Delgado province results in a total province cost for one year of $305,418.80 for a total of $5.03 per child receiving DPT-Hep B3 and $1.18 per vaccine dose delivered. The table below details these costs and the following sections provide an analysis of these results.

Table 6: Total Cabo Delgado System Costs for 1 Year

	Totals From Data	Entire Province Estimate	Entire Province Estimate	$/dose delivered	% of Total
Transport					
	(one month)	(one month)	(12 months)		
Monthly Costs					18.08%
Vehicle Breakdown Cost	$171.75	$171.75	$2,061.00	$0.00	
Public Transport Usage Cost	$0.00	$0.00	$0.00	$0.00	
Fuel Costs	$949.46	$949.46	$11,393.55	$0.01	
Vehicle Depreciation	$2,073.92	$2,073.92	$24,887.05	$0.03	
Scheduled Vehicle Maintenance	$714.74	$714.74	$8,576.88	$0.01	
Insurance Costs	$693.00	$693.00	$8,316.00	$0.01	
Total Transport Costs	$4,602.87	$4,602.87	$55,234.48	$0.06	
Personnel					
Monthly Costs					11.58%
Salaries	$1,440.00	$1,440.00	$17,280.00	$0.02	
Per Diems	$1,508.00	$1,508.00	$18,096.00	$0.02	
Total Transportation Personnel Costs	$2,948.00	$2,948.00	$35,376.00	$0.04	
Cold Chain					
Monthly Costs					8.90%
Fuel Costs	$1,920.00	$1,920.00	$23,040.00	$0.03	
Costs Recurring Variably					
Refrigerator Breakdown: Labor Costs	$8.54	$8.54	$102.44	$0.00	
Refrigerator Breakdown: Transport Costs	$38.57	$38.57	$462.81	$0.00	
Refrigerator Breakdown: All Other Costs	$298.88	$298.88	$3,586.57	$0.00	
Total Refrigerator Breakdown Costs	$345.98	$345.98	$4,151.82	$0.00	
Total Refrigeration Costs	$2,265.98	$2,265.98	$27,191.82	$0.03	
Vaccines & Supplies					
BCG Vaccine	$1,673.68	$1,673.68	$20,084.19	$0.15	61.43%
DPT-Hep B Vaccine	$2,755.27	$2,755.27	$33,063.26	$0.18	
VAP Vaccine	$5,036.71	$5,036.71	$60,440.47	$0.21	
VAS Vaccine	$1,211.93	$1,211.93	$14,543.16	$0.20	
VAT Vaccine	$1,575.62	$1,575.62	$18,907.43	$0.10	
0.5 ml Syringe	$2,725.13	$2,725.13	$32,701.50	$0.08	
0.05 ml Syringe	$629.33	$629.33	$7,552.02	$0.10	
5 ml Syringe	$27.04	$27.04	$324.48	$0.04	
Total Vaccine Costs	$15,634.71	$15,634.71	$187,616.51	$1.04	
Total Incremental Cost					
Total Cost:	$25,451.57	$25,451.57	$305,418.80	$1.18	
Total Number of Children DPT-Hep B3 Vaccinated	5,063	5,063	60,760		
Estimated Cost per Child DPT-Hep B3 Vaccinated	$5.03	$5.03	$5.03		
Total Number of Children Under Age 5	303,007	303,007	303,007		
Total Cost Per Child Under Age 5	$0.08	$0.08	$1.01		
Total Number of Vaccine Doses Delivered	74,096	74,096	889,152		
Total Cost Per Dose Delivered	$1.18	$1.18	$1.18		

Analysis of Personnel Costs

Personnel costs were limited to the salaries and per diems of the field coordinators and the drivers. Each team, consisting of one field coordinator and one driver, covered one zone, approximately 30-40 health centers each month. Because the field coordinators and drivers were hired with the primary task to manage logistics in the system, 100% of their salary was included in the model. The salaries of the two positions were 7,350 MZN ($294) and 4,650 MZN ($186) per month. The teams were also paid per diems to cover expenses for time spent in the field, which was approximately 8-12 days per month. Due to the high number of days the field teams spent in the field, a per diem rate lower than the national rate was negotiated for these teams. The national rate is 1125 MZN ($45) for field coordinators and 937.5 MZN ($37.50) for drivers, but the rate negotiated for the field coordinators and drivers was 725 MZN ($29). This rate was negotiated for both provinces where the Project to Support PAV operated.

Analysis of Transport Costs

The transport costs included the full purchase, insurance, fuel, maintenance, and repair costs for the three open cab Toyota Land Cruisers that were used for the vaccine logistics in Cabo Delgado. Because these vehicles were used exclusively for vaccine logistics, 100% of their costs were included. With the exception of fuel, the costs were based on actual expenditures. The cost of fuel was based on the same cost per liter as in the Niassa costing model to control for changing fuel prices.

Analysis of Cold Chain Costs

The costs of maintaining a cold chain were based on the use of 80 gas refrigerators and eight solar refrigerators in the province. Both costs were based on data collected from the province and national level maintenance departments. The number of breakdowns was based on the actual number of refrigerator breakdowns incurred during 2006.

Analysis of vaccine and other Supply Commodity Costs

The vaccine and syringe data included a wastage factor[15] using the actual open and closed vial wastage rates for 2006 in Cabo Delgado province. Similarly, the number of vaccines and syringes used and number of children receiving a DPT-Hep B3 vaccination were based on actual numbers.

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[15] Wastage factor is 100/ (100-Wastage Rate) as used by the World Health Organization. Details on this factor can be found at http://www.who.int/immunization_delivery/vaccine_management_logistics/logistics/expected_wastage/en/index.html.

Appendix C: Analysis of Results for Niassa Costs

The field work in Niassa found a vaccine logistics system with great variability in activities and costs. Additionally, the costs of operating a vaccine logistics system in Niassa were not directly recorded and allocated as they were in Cabo Delgado province. For these reasons, this study calculated a range of costs for the Niassa vaccine logistics system. This range was estimated to be between $5.04 to $7.19 per child vaccinated with DPT-Hep B3 and $1.41 to $1.60 per vaccine dose delivered. However, running the cost model for Niassa province resulted in an estimated incurred cost for one year is $266,563.04 for vaccine logistics, a cost per child vaccinated with DPT-Hep B3 of $6.07, and a cost per vaccine dose delivered of $1.50.

The table below details the estimated incurred costs and the following sections provide an analysis of these results followed by an explanation and discussion of the range of costs.[16]

[16] In Niassa, a sample of the costs for one month was entered into the cost model. Therefore, the "Totals from Data" represent only a portion of the full province costs and "Entire Province Estimate" costs are modeled from the sample.

Table 7: Total Niassa Modeled System Costs for 1 Year

	Totals From Data	Entire Province Estimate	Entire Province Estimate	$/dose delivered	% of Total
	(one month)	(one month)	(12 months)		
Transport					
Monthly Costs					
Vehicle Breakdown Cost	**$28.72**	**$312.70**	**$3,752.38**	$0.01	13.49%
Public Transport Usage Cost	**$11.26**	**$122.57**	**$1,470.78**	$0.00	
Fuel Costs	**$55.98**	**$609.51**	**$7,314.13**	$0.01	
Vehicle Depreciation	**$72.16**	**$785.76**	**$9,429.17**	$0.02	
Scheduled Vehicle Maintenance	**$101.69**	**$1,107.29**	**$13,287.44**	$0.03	
Insurance Costs	**$5.47**	**$59.54**	**$714.49**	$0.00	
Total Transport Costs	**$275.27**	**$2,997.37**	**$35,968.39**	$0.07	
Personnel					
Monthly Costs					
Salaries	**$76.30**	**$830.78**	**$9,969.32**	$0.02	28.32%
Per Diems	**$501.37**	**$5,459.41**	**$65,512.92**	$0.13	
Total Transportation Personnel Costs	**$577.67**	**$6,290.19**	**$75,482.23**	$0.15	
Cold Chain					
Monthly Costs					
Fuel Costs	**$84.92**	**$924.68**	**$11,096.21**	$0.02	11.74%
Costs Recurring Variably					
Refrigerator Breakdown: Labor Costs	**$6.67**	**$72.63**	**$871.57**	$0.00	
Refrigerator Breakdown: Transport Costs	**$30.76**	**$334.90**	**$4,018.79**	$0.01	
Refrigerator Breakdown: All Other Costs	**$117.24**	**$1,276.65**	**$15,319.85**	$0.03	
Total Refrigerator Breakdown Costs	**$154.67**	**$1,684.19**	**$20,210.30**	$0.04	
Total Refrigeration Costs	**$239.59**	**$2,608.87**	**$31,306.42**	$0.06	
Vaccines & Supplies					
BCG Vaccine	**$110.70**	**$1,205.40**	**$14,464.80**	$0.21	46.45%
DPT-Hep B Vaccine	**$233.03**	**$2,537.39**	**$30,448.72**	$0.20	
VAP Vaccine	**$258.15**	**$2,810.99**	**$33,731.83**	$0.22	
VAS Vaccine	**$82.43**	**$897.52**	**$10,770.20**	$0.26	
VAT Vaccine	**$65.75**	**$715.98**	**$8,591.72**	$0.11	
0.5 ml Syringe	**$158.94**	**$1,730.73**	**$20,768.75**	$0.08	
0.05 ml Syringe	**$37.00**	**$402.86**	**$4,834.30**	$0.10	
5 ml Syringe	**$1.50**	**$16.31**	**$195.69**	$0.04	
Total Vaccine Costs	**$947.49**	**$10,317.17**	**$123,806.00**	$1.21	
Total Incremental Cost					
Total Cost:	**$2,040.02**	**$22,213.59**	**$266,563.04**	**$1.50**	
Total Number of Children DPT-Hep B3 Vaccinated	**336**	**3,661**	**43,937**		
Estimated Cost per Child DPT-Hep B3 Vaccinated	**$6.07**	**$6.07**	**$6.07**		
Total Number of Children Under Age 5	**179,892**	**179,892**	**179,892**		
Total Cost Per Child Under Age 5	**$0.01**	**$0.12**	**$1.48**		
Total Number of Vaccine Doses Delivered	**3,816**	**41,552**	**498,624**		
Total Cost Per Dose Delivered	**$1.50**	**$1.50**	**$1.50**		

Analysis of Personnel Costs

In Niassa, the personnel costs were based on salary and per diems actually incurred to distribute vaccines during a three-month sample at nine health centers in eight districts. A wide range of personnel at all levels of the health system were involved in vaccine distribution. A DPS manager reported that drivers, administrators, and others who do not know about vaccine handling often come to pick up vaccines and their lack of knowledge results in problems transporting and conserving the vaccines during transport to maintain their efficacy. Monthly salaries of the personnel ranged from 1,700 MZN ($68) to 5,400 MZN ($216). The following personnel were used at some point in the supply chain to distribute vaccines to the sample health centers in Niassa:

1. Provincial PAV Chief
2. Provincial Logistics Officer
3. District Administrator
4. District Director of Services
5. Responsible for PAV at the district and health center level
6. Responsible for the Health Center
7. Health Unit Service Agent
8. Pharmacy Technician
9. Midwife
10. Nurse
11. Driver
12. Driver's Assistant

Analysis of Transport Costs

The field work in Niassa found six forms of transport used in vaccine distribution: open cab Toyota Land Cruiser, a closed cab Toyota Land Cruiser used as an ambulance, motorcycles (mostly Honda XL125), bicycles, chapa (buses), and walking. The costs of these methods of transport as they were used for vaccine distribution were included in the cost modeling.

Vehicle depreciation was based on an average actual life of a sampling of ambulances, trucks and motorcycles, which corresponded very closely to the national policy of five years. Vehicle insurance costs were included in the model, but a DPS survey respondent reported there is a lack of funds to pay vehicle insurance. Consequently, in 2008 DPS Niassa paid insurance for 21 of the 62 vehicles in their fleet.[17] Additionally, no insurance is paid on motorcycles so no motorcycle insurance cost was included in the model.

The fuel cost was based on the cost per kilometer driven for vaccine distribution and the vehicle fuel efficiency, which was taken as the average fuel efficiency reported by the various respondents. For example, fuel efficiency for open cab Toyota Land Cruisers was provided by seven respondents and varied from 4.3 km/L to 7.5 km/L. The average used in the model was 5.6 km/L.

Vehicle maintenance cost was modeled based on the cost of maintenance per kilometer driven allocated to vaccine distribution. These costs were obtained from DPS and district transport departments which identified the maintenance schedule for vehicles. Survey respondents noted that actual vehicle maintenance performed differs from the maintenance schedule due to various constraints.

Vehicle breakdown costs were based on the costs of labor and parts for breakdowns identified as an easy level of effort to fix, medium level, and difficult level and a percentage of the total breakdowns assigned to each category. These costs were based on surveying the provincial transport department and seven district transport departments. The vehicle repair costs do not include traveling to broken vehicles to perform the repairs or traveling to the cities to purchase spare parts, thus it is possible that some staff time and per diems are excluded from this cost.

[17] Accordingly, the estimated incurred costs to operate the vaccine logistics system in Niassa includes the payment of 34% of insurance costs.

Similar to vehicle maintenance, survey responses clearly indicated it cannot be assumed that 100% of the vehicle breakdowns are repaired due to various constraints.

Analysis of Cold Chain Costs

The field work in Niassa found many challenges in the cold chain. DPS reported there are many recurring cold chain problems: broken fans, burners, and tanks, in addition to frequent theft of solar panels. Many respondents noted the lack of refrigerator maintenance knowledge in the health centers where the refrigerators are used. Several districts reported refrigerators break down often and sometimes for very long periods due to the lack of maintenance, old age, and lack of spare parts. The last preventive maintenance training in the province was in 2006 for three days and a survey respondent noted that most of the breakdowns happen because health workers don't know how to maintain the equipment properly. DPS also reported that refrigerator repairs are often complicated by the lack of transport, per diem funds, and basic tools. The duration of refrigerator breakdowns varied from one day to more than one year. One district reported having a health center with a refrigerator that was installed improperly and never worked.

The DPS Maintenance Department reported that no costs were spent on maintenance because they did not have the transport or per diem budget to access the refrigerators for maintenance activities. Any maintenance completed was done in the health centers, which as described above, is problematic.

Refrigerator repair costs were calculated in a similar manner to the vehicle repair costs such that they are based on finding the costs of labor and parts for breakdowns with an easy level of effort to fix, medium level, and difficult level and a percentage of the total breakdowns assigned to each category. The repair costs included the cost of labor, per diems, and parts for repairs. The cost of transport to get to the broken refrigerators was not included in these costs. Due to the centralized nature of cold chain management, refrigerator costs were difficult to obtain at the provincial and district level, so the data was triangulated by also administering the survey at the MISAU Maintenance Department.

Analysis of Vaccine and Other Supply Commodity Costs

The vaccine and syringe data from Cabo Delgado used a wastage factor[18] based on the actual wastage rates incurred in 2006, but actual wastage rates from Niassa were unavailable. Therefore, the model used the national expected open and closed vial wastage rates for 2009 based on the national Stock Management Tool completed in April 2009. Similarly, the Stock Management Tool was used to gather data about the number of syringes needed. The number of vaccines doses used and children receiving a DPT-Hep B3 vaccination was sourced from the national Health Information System 2008 annual output.

Assumptions Used in Modeling the Niassa Vaccine Logistics Costs

The complex system in Niassa required several assumptions, as demonstrated by the variety of survey responses discussed above. The high and low estimates for these assumptions were run in the model to understand how they affected the costs.

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[18] Wastage factor is 100/ (100-Wastage Rate) as used by the World Health Organization. Details on this factor can be found at http://www.who.int/immunization_delivery/vaccine_management_logistics/logistics/expected_wastage/en/index.html.

To gather the lowest estimate of costs, the combination of assumptions that decreased the costs the most was input into the model. With all of the assumptions at the low estimate, the modeled absolute annual cost of running the vaccine logistics system in Niassa province is $221,558, the cost per child vaccinated with DPT-Hep B3 is $5.04 and the cost per vaccine dose delivered is $1.41. See the detailed output below.

Table 8: Niassa Vaccine Logistics System Modeled for One Year All Low Estimates and Assumptions

Transport					
	Totals From Data	**Entire Province Estimate**	**Entire Province Estimate**	**$/vaccine dose delivered**	**% of Total**
	(one month)	**(one month)**	**(12 months)**		
Monthly Costs					
Vehicle Breakdown Cost	**$9.29**	**$101.19**	**$1,214.31**	$0.00	9.57%
Public Transport Usage Cost	**$11.26**	**$122.57**	**$1,470.78**	$0.00	
Fuel Costs	**$44.42**	**$483.71**	**$5,804.51**	$0.01	
Vehicle Depreciation	**$55.73**	**$606.85**	**$7,282.25**	$0.01	
Scheduled Vehicle Maintenance	**$39.65**	**$431.72**	**$5,180.60**	$0.01	
Insurance Costs	**$1.95**	**$21.25**	**$255.05**	$0.00	
Total Transport Costs	**$162.30**	**$1,767.29**	**$21,207.50**	$0.04	
Personnel					
Monthly Costs					27.80%
Salaries	**$61.20**	**$666.35**	**$7,996.23**	$0.02	
Per Diems	**$410.11**	**$4,465.59**	**$53,587.08**	$0.11	
Total Transportation Personnel Costs	**$471.30**	**$5,131.94**	**$61,583.31**	$0.12	
Cold Chain					
Monthly Costs					6.75%
Refrigerator: Depreciation	**$0.00**	**$0.00**	**$0.00**	$0.00	
Fuel Costs	**$84.92**	**$924.68**	**$11,096.21**	$0.02	
Costs Recurring Variably				$0.00	
Refrigerator Breakdown: Labor Costs	**$1.22**	**$13.34**	**$160.07**	$0.00	
Refrigerator Breakdown: Transport Costs	**$5.66**	**$61.63**	**$739.61**	$0.00	
Refrigerator Breakdown: All Other Costs	**$22.70**	**$247.12**	**$2,965.50**	$0.01	
Total Refrigerator Breakdown Costs	**$29.58**	**$322.10**	**$3,865.19**	$0.01	
Total Refrigeration Costs	**$114.50**	**$1,246.78**	**$14,961.39**	$0.03	
Vaccines & Supplies					
BCG Vaccine	**$110.70**	**$1,205.40**	**$14,464.80**	$0.21	55.88%
DPT-Hep B Vaccine	**$233.03**	**$2,537.39**	**$30,448.72**	$0.20	
VAP Vaccine	**$258.15**	**$2,810.99**	**$33,731.83**	$0.22	
VAS Vaccine	**$82.43**	**$897.52**	**$10,770.20**	$0.26	
VAT Vaccine	**$65.75**	**$715.98**	**$8,591.72**	$0.11	
0.5 ml Syringe	**$158.94**	**$1,730.73**	**$20,768.75**	$0.08	
0.05 ml Syringe	**$37.00**	**$402.86**	**$4,834.30**	$0.10	
5 ml Syringe	**$1.50**	**$16.31**	**$195.69**	$0.04	
Total Vaccine Costs	**$947.49**	**$10,317.17**	**$123,806.00**	$1.21	
Total Incremental Cost Over 12 Months					
Total Cost:	**$1,695.60**	**$18,463.18**	**$221,558.20**	**$1.41**	
Total Number of Children DPT-Hep B3 Vaccinated	**336**	**3,661**	**43,937**		
Estimated Cost per Child DPT-Hep B3 Vaccinated	**$5.04**	**$5.04**	**$5.04**		
Total Number of Children Under Age 5	**179,892**	**179,892**	**179,892**		
Total Cost Per Child Under Age 5	**$0.01**	**$0.10**	**$1.23**		
Total Number of Vaccine Doses Delivered	**3,816**	**41,552**	**498,624**		
Total Cost Per Dose Delivered	**$1.41**	**$1.41**	**$1.41**		

Similarly, to gather the highest estimates of costs, the combination of assumptions with the highest cost was entered in the model. With these assumptions, the modeled absolute annual cost of running the vaccine logistics system in Niassa province is $316,064, the cost per child vaccinated with DPT-Hep B3 is $7.19 and the cost per vaccine dose delivered is $1.60. See the detailed output below.

Table 9: Niassa Vaccine Logistics System Modeled for One Year All High Estimates and Assumptions

Transport					
	Totals From Data	**Entire Province Estimate**	**Entire Province Estimate**	**$/vaccine dose delivered**	**% of Total**
	(one month)	**(one month)**	**(12 months)**		
Monthly Costs					
Vehicle Breakdown Cost	**$67.88**	**$739.15**	**$8,869.74**	$0.02	
Public Transport Usage Cost	**$11.26**	**$122.57**	**$1,470.78**	$0.00	
Fuel Costs	**$55.98**	**$609.51**	**$7,314.13**	$0.01	17.64%
Vehicle Depreciation	**$72.16**	**$785.76**	**$9,429.17**	$0.02	
Scheduled Vehicle Maintenance	**$203.38**	**$2,214.57**	**$26,574.87**	$0.05	
Insurance Costs	**$16.08**	**$175.12**	**$2,101.45**	$0.00	
Total Transport Costs	**$426.74**	**$4,646.68**	**$55,760.15**	$0.11	
Personnel					
Monthly Costs					
Salaries	**$76.30**	**$830.78**	**$9,969.32**	$0.02	23.88%
Per Diems	**$501.37**	**$5,459.41**	**$65,512.92**	$0.13	
Total Transportation Personnel Costs	**$577.67**	**$6,290.19**	**$75,482.23**	$0.15	
Cold Chain					
Monthly Costs					
Refrigerator: Depreciation	**$0.00**	**$0.00**	**$0.00**	$0.00	
Fuel Costs	**$84.92**	**$924.68**	**$11,096.21**	$0.02	
Costs Recurring Variably				$0.00	
Refrigerator Breakdown: Labor Costs	**$16.88**	**$183.81**	**$2,205.77**	$0.00	19.30%
Refrigerator Breakdown: Transport Costs	**$77.74**	**$846.52**	**$10,158.26**	$0.02	
Refrigerator Breakdown: All Other Costs	**$287.41**	**$3,129.62**	**$37,555.40**	$0.08	
Total Refrigerator Breakdown Costs	**$382.04**	**$4,159.97**	**$49,919.62**	$0.10	
Total Refrigeration Costs	**$466.96**	**$5,084.64**	**$61,015.64**	$0.12	
Vaccines & Supplies					
BCG Vaccine	**$110.70**	**$1,205.40**	**$14,464.80**	$0.21	
DPT-Hep B Vaccine	**$233.03**	**$2,537.39**	**$30,448.72**	$0.20	
VAP Vaccine	**$258.15**	**$2,810.99**	**$33,731.83**	$0.22	
VAS Vaccine	**$82.43**	**$897.52**	**$10,770.20**	$0.26	
VAT Vaccine	**$65.75**	**$715.98**	**$8,591.72**	$0.11	39.17%
0.5 ml Syringe	**$158.94**	**$1,730.73**	**$20,768.75**	$0.08	
0.05 ml Syringe	**$37.00**	**$402.86**	**$4,834.30**	$0.10	
5 ml Syringe	**$1.50**	**$16.31**	**$195.69**	$0.04	
Total Vaccine Costs	**$947.49**	**$10,317.17**	**$123,806.00**	$1.21	
Total Incremental Cost Over 12 Months					
Total Cost:	**$2,418.86**	**$26,338.67**	**$316,064.02**	**$1.60**	
Total Number of Children DPT-Hep B3 Vaccinated	**336**	**3,661**	**43,937**		
Estimated Cost per Child DPT-Hep B3 Vaccinated	**$7.19**	**$7.19**	**$7.19**		
Total Number of Children Under Age 5	**179,892**	**179,892**	**179,892**		
Total Cost Per Child Under Age 5	**$0.01**	**$0.15**	**$1.76**		
Total Number of Vaccine Doses Delivered	**3,816**	**41,552**	**498,624**		
Total Cost Per Dose Delivered	**$1.60**	**$1.60**	**$1.60**		

To determine the estimated incurred cost, the combination of assumptions that most matches the qualitative information gathered during the field work was entered in the model. As written at the beginning of this section, the result of these assumptions was the modeled absolute annual cost of running the vaccine logistics system in Niassa province of $266,563 with the cost per child vaccinated with DPT-Hep B3 of $6.07 and a cost per vaccine dose delivered of $1.50. The table below lists the various assumptions included in the Niassa cost modeling and the values that were used for the high, low, and estimated incurred costs.

Table 10: Niassa Cost Modeling Assumptions with High, Low, and Estimated Incurred Values

Assumption	Low Cost Value	High Cost Value	Estimated Incurred Costs
Percent of refrigerator problems that are fixed	25%	100%	50%
Cost estimates of refrigerator breakdowns	50%	Average of various respondent's costs	Average of various respondent's costs
Classification of refrigerator problems: Easy, Difficult	100% easy 0% difficult	50% easy 50% difficult	75% easy 25% difficult
Percent of vehicle breakdowns that are fixed	25%	100%	50%
Percent of vehicle maintenance that is completed	25%	100%	50%
Percent of maintenance costs allocated to PAV vehicle use	20%	50%	33%
Cost estimates of vehicle breakdowns	50%	Average of various respondent's costs	Average of various respondent's costs
Classification of vehicle breakdowns: Easy, Medium, Difficult	60% easy 30% medium 10% difficult	33% easy 33% medium 33% difficult	41.5% easy 41.5% medium 17% difficult
Percent of vehicles that are insured	15%	100%	34%
Percent of the vaccine distribution transport leg that was for vaccines (in all cases where respondent said "majority")	50%	75%	75%

To further understand the effect of the assumptions on the costs, each of the assumptions were entered into the model individually holding all other costs constant from the estimated incurred cost value model (values held constant are the third column in the table above). The table and graph below show the assumptions and the outcome when running the high and low values for the assumptions.

Graph 5: Niassa High and Low Assumption Modeled Outcomes with All Other Assumptions Held Constant

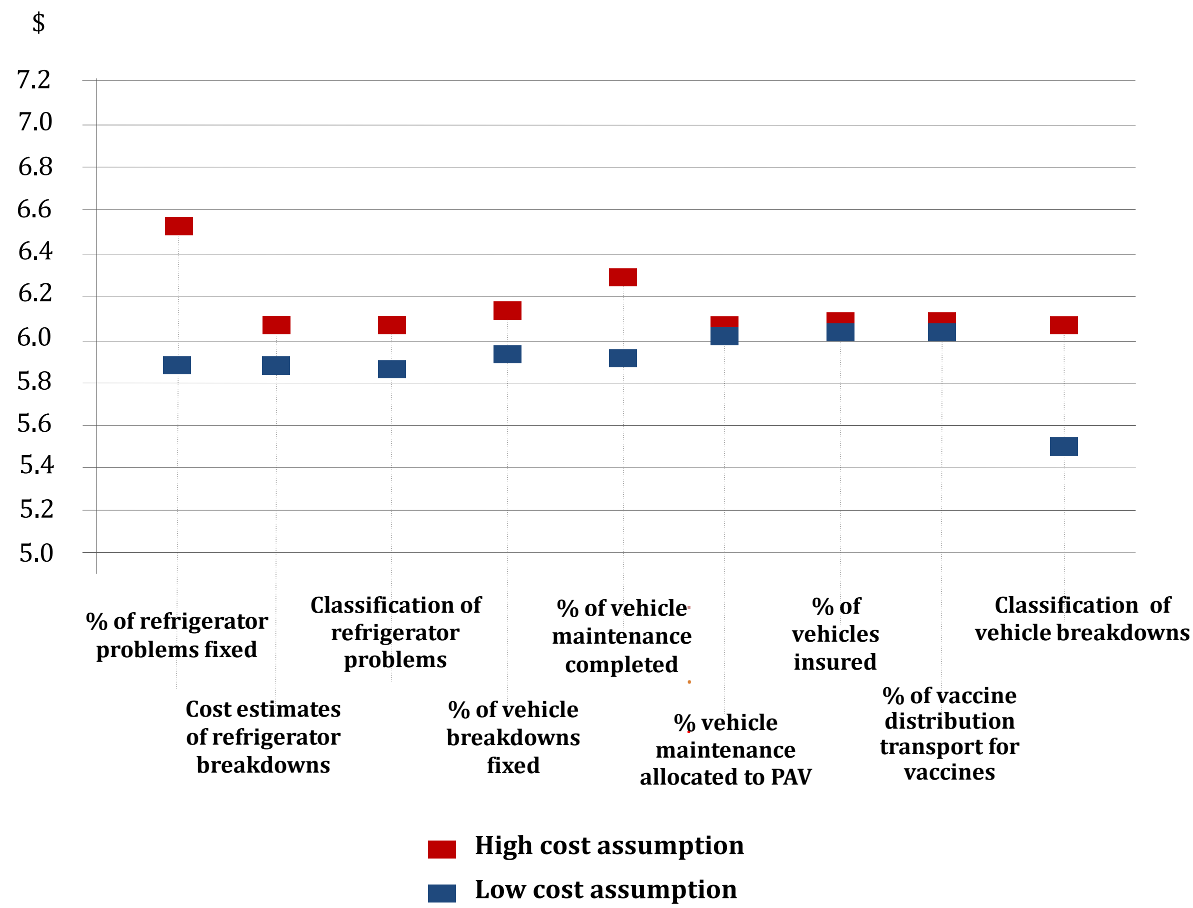

Table 11: Niassa High and Low Assumption Values and Modeled Outcomes with all other Assumptions Held Constant

Assumption	**Low Cost Value & *Result:*** ***Absolute Annual*** ***Per DPT-Hep B3 Vaccination***	**High Cost Value & *Result*** ***Absolute Annual*** ***Per DPT-Hep B3 Vaccination***
Percent of refrigerator problems that are fixed	25% *$256,458* *$5.84*	100% *$286,773* *$6.53*
Cost estimates of refrigerator breakdowns	50% *$256,458* *$5.84*	Average of various respondent's costs *$266,563* *$6.07*

Classification of refrigerator problems: Easy, Difficult	100% easy 0% difficult *$261,813* *$5.96*	50% easy 50% difficult *$271,312* *$6.18*
Percent of vehicle breakdowns that are fixed	25% *$265,072* *$6.03*	100% *$269,545* *$6.13*
Percent of vehicle maintenance that is completed	25% *$259,412* *$5.90*	100% *$277,824* *$6.32*
Cost estimates of vehicle breakdowns	50% *$265,072* *$6.03*	Average of various respondent's costs *$266,563* *$6.07*
Classification of vehicle breakdowns: Easy, Medium, Difficult	60% easy 30% medium 10% difficult *$265,814* *$6.05*	33% easy 33% medium 33% difficult *$267,467* *$6.09*
Percent of vehicles that are insured	15% *$266,164* *$6.06*	100% *$267,950* *$6.10*
Percent of the vaccine distribution transport leg that was for vaccines (in all cases where respondent said "majority")	50% *$245,248* *$5.58*	Average of various respondent's costs *$266,563* *$6.07*

Appendix D: System Costs Including Cold Chain Depreciation

Although the cost model developed for this study accommodates the cost of cold chain depreciation, it was excluded from the main analysis in this report due to the very different cold chain infrastructures in the two provinces. When we include cold chain depreciation, cold chain costs over one year are $148,477.58 higher in Niassa province over Cabo Delgado province. Most of this increase comes in the refrigerator depreciation, which is $144,362.98 higher for one year in Niassa. Although the depreciation costs account for the new cold chain that was installed in Cabo Delgado in 2002-2004, the depreciation costs are much higher in Niassa due to the large number of solar refrigerators, which are significantly more expensive than all other refrigerator types. Mozambique's Ministry of Health purchases solar refrigerators (including generators) for $10,000 and solar refrigerators account for approximately half of the refrigerators in Niassa province. In Cabo Delgado province, however, gas refrigerators comprise approximately 90% of refrigerators and their purchase price is only $1,500. Both types of refrigerators have the same useful life of five years, which results in a significantly higher depreciation cost for solar refrigerators and therefore the cold chain portion of the vaccine logistics system in Niassa. The tables below show the results when running the model including cold chain depreciation costs.

Table 12: Niassa Vaccine Logistics System Modeled for One Year Including Cold Chain Depreciation

	Totals From Data	Entire Province Estimate	Entire Province Estimate	$/vaccine dose delivered	% of Total
Transport					
	(one month)	(one month)	(12 months)		
Monthly Costs					7.90%
Vehicle Breakdown Cost	**$28.72**	**$312.70**	**$3,752.38**	$0.01	
Public Transport Usage Cost	**$11.26**	**$122.57**	**$1,470.78**	$0.00	
Fuel Costs	**$55.98**	**$609.51**	**$7,314.13**	$0.01	
Vehicle Depreciation	**$72.16**	**$785.76**	**$9,429.17**	$0.02	
Scheduled Vehicle Maintenance	**$101.69**	**$1,107.29**	**$13,287.44**	$0.03	
Insurance Costs	**$5.47**	**$59.54**	**$714.49**	$0.00	
Total Transport Costs	**$275.27**	**$2,997.37**	**$35,968.39**	$0.07	
Personnel					
Monthly Costs					16.58%
Salaries	**$76.30**	**$830.78**	**$9,969.32**	$0.02	
Per Diems	**$501.37**	**$5,459.41**	**$65,512.92**	$0.13	
Total Transportation Personnel Costs	**$577.67**	**$6,290.19**	**$75,482.23**	$0.15	
Cold Chain					
Monthly Costs					48.33%
Refrigerator: Depreciation	**$1,444.52**	**$15,729.17**	**$188,750.10**	$0.38	
Fuel Costs	**$84.92**	**$924.68**	**$11,096.21**	$0.02	
Costs Recurring Variably				$0.00	
Refrigerator Breakdown: Labor Costs	**$6.67**	**$72.63**	**$871.57**	$0.00	
Refrigerator Breakdown: Transport Costs	**$30.76**	**$334.90**	**$4,018.79**	$0.01	
Refrigerator Breakdown: All Other Costs	**$117.24**	**$1,276.65**	**$15,319.85**	$0.03	
Total Refrigerator Breakdown Costs	**$154.67**	**$1,684.19**	**$20,210.30**	$0.04	
Total Refrigeration Costs	**$1,684.11**	**$18,338.04**	**$220,056.52**	$0.44	
Vaccines & Supplies					
BCG Vaccine	**$110.70**	**$1,205.40**	**$14,464.80**	$0.21	27.19%
DPT-Hep B Vaccine	**$233.03**	**$2,537.39**	**$30,448.72**	$0.20	
VAP Vaccine	**$258.15**	**$2,810.99**	**$33,731.83**	$0.22	
VAS Vaccine	**$82.43**	**$897.52**	**$10,770.20**	$0.26	
VAT Vaccine	**$65.75**	**$715.98**	**$8,591.72**	$0.11	
0.5 ml Syringe	**$158.94**	**$1,730.73**	**$20,768.75**	$0.08	
0.05 ml Syringe	**$37.00**	**$402.86**	**$4,834.30**	$0.10	
5 ml Syringe	**$1.50**	**$16.31**	**$195.69**	$0.04	
Total Vaccine Costs	**$947.49**	**$10,317.17**	**$123,806.00**	$1.21	
Total Incremental Cost					
Total Cost:	**$3,484.54**	**$37,942.76**	**$455,313.14**	**$1.88**	
Total Number of Children DPT-Hep B3 Vaccinated	**336**	**3,661**	**43,937**		
Estimated Cost per Child DPT-Hep B3 Vaccinated	**$10.36**	**$10.36**	**$10.36**		
Total Number of Children Under Age 5	**179,892**	**179,892**	**179,892**		
Total Cost Per Child Under Age 5	**$0.02**	**$0.21**	**$2.53**		
Total Number of Vaccine Doses Delivered	**3,816**	**41,552**	**498,624**		
Total Cost Per Dose Delivered	**$1.88**	**$1.88**	**$1.88**		

Table 13: Cabo Delgado Vaccine Logistics System Modeled for One Year Including Cold Chain Depreciation

	Totals From Data	Entire Province Estimate	Entire Province Estimate	$/vaccine dose delivered	% of Total
Transport					
	(one month)	**(one month)**	**(12 months)**		
Monthly Costs					
Vehicle Breakdown Cost	**$171.75**	**$171.75**	**$2,061.00**	$0.00	15.79%
Public Transport Usage Cost	**$0.00**	**$0.00**	**$0.00**	$0.00	
Fuel Costs	**$949.46**	**$949.46**	**$11,393.55**	$0.01	
Vehicle Depreciation	**$2,073.92**	**$2,073.92**	**$24,887.05**	$0.03	
Scheduled Vehicle Maintenance	**$714.74**	**$714.74**	**$8,576.88**	$0.01	
Insurance Costs	**$693.00**	**$693.00**	**$8,316.00**	$0.01	
Total Transport Costs	**$4,602.87**	**$4,602.87**	**$55,234.48**	$0.06	
Personnel					
Monthly Costs					
Salaries	**$1,440.00**	**$1,440.00**	**$17,280.00**	$0.02	10.11%
Per Diems	**$1,508.00**	**$1,508.00**	**$18,096.00**	$0.02	
Total Transportation Personnel Costs	**$2,948.00**	**$2,948.00**	**$35,376.00**	$0.04	
Cold Chain					
Monthly Costs					
Refrigerator: Depreciation	**$3,698.93**	**$3,698.93**	**$44,387.12**	$0.05	20.46%
Fuel Costs	**$1,920.00**	**$1,920.00**	**$23,040.00**	$0.03	
Costs Recurring Variably				$0.00	
Refrigerator Breakdown: Labor Costs	**$8.54**	**$8.54**	**$102.44**	$0.00	
Refrigerator Breakdown: Transport Costs	**$38.57**	**$38.57**	**$462.81**	$0.00	
Refrigerator Breakdown: All Other Costs	**$298.88**	**$298.88**	**$3,586.57**	$0.00	
Total Refrigerator Breakdown Costs	**$345.98**	**$345.98**	**$4,151.82**	$0.00	
Total Refrigeration Costs	**$5,964.91**	**$5,964.91**	**$71,578.94**	$0.08	
Vaccines & Supplies					
BCG Vaccine	**$1,673.68**	**$1,673.68**	**$20,084.19**	$0.15	53.63%
DPT-Hep B Vaccine	**$2,755.27**	**$2,755.27**	**$33,063.26**	$0.18	
VAP Vaccine	**$5,036.71**	**$5,036.71**	**$60,440.47**	$0.21	
VAS Vaccine	**$1,211.93**	**$1,211.93**	**$14,543.16**	$0.20	
VAT Vaccine	**$1,575.62**	**$1,575.62**	**$18,907.43**	$0.10	
0.5 ml Syringe	**$2,725.13**	**$2,725.13**	**$32,701.50**	$0.08	
0.05 ml Syringe	**$629.33**	**$629.33**	**$7,552.02**	$0.10	
5 ml Syringe	**$27.04**	**$27.04**	**$324.48**	$0.04	
Total Vaccine Costs	**$15,634.71**	**$15,634.71**	**$187,616.51**	$1.04	
Total Incremental Cost					
Total Cost:	**$29,150.49**	**$29,150.49**	**$349,805.92**	**$1.23**	
Total Number of Children DPT-Hep B3 Vaccinated	**5,063**	**5,063**	**60,760**		
Estimated Cost per Child DPT-Hep B3 Vaccinated	**$5.76**	**$5.76**	**$5.76**		
Total Number of Children Under Age 5	**303,007**	**303,007**	**303,007**		
Total Cost Per Child Under Age 5	**$0.10**	**$0.10**	**$1.15**		
Total Number of Vaccine Doses Delivered	**74,096**	**74,096**	**889,152**		
Total Cost Per Dose Delivered	**$1.23**	**$1.23**	**$1.23**		

Table 14: Summary of Niassa and Cabo Delgado Vaccine Characteristics and Logistics System Costs Including Cold Chain Depreciation Costs

Characteristic / Comparison	**Niassa**	**Cabo Delgado**	**Difference**
Absolute Costs			
Population	1,178,117	1,632,809	-454,692
Total Vaccine Logistics Costs for 1 Year	$455,313.14	$349,805.92	$105,507.22
Transport	*$ 35,968.39 (8%)*	*$ 55,234.48 (16%)*	*-$19,266.09 (-16%)*
Personnel	*$75,482.23 (17%)*	*$ 35,376.00 (10%)*	*+$40,106.23 (7%)*
Cold Chain	*$220,056.52 (48%)*	*$71,578.94 (20%)*	*+$148,477.28 (28%)*
Vaccines & Supplies	*$123,806.00 (27%)*	*$187,616.51 (54%)*	*-$63,810.51 (27%)*
Costs Controlling for Population Differences			
Population of Children Under 5 Years	179,892	303,007	-123,115
Total Cost Per Child Under 5 in 1 Year	$2.53	$1.15	$1.38
Relative Cost-Effectiveness			
DPT3 2008 Coverage Rate among children aged 24-35 months[19]	70%	95.4%	-25.4%
Total Cost Per Child Receiving DPT-Hep B3 in 1 Year	$10.36	$5.76	$4.60
Relative Cost-Efficiency			
Number of Vaccine Doses Delivered in 1 Year	498,624	889,152	-390,528
Total Cost Per Dose of Vaccine Delivered	$1.88	$1.23	$0.65

[19] See *Evaluation of the Project to Support PAV (Expanded Program on Immunization) In Northern Mozambique, 2001-2008: An Independent Review for VillageReach with Program and Policy Recommendations* for details of the coverage rates.

The table above shows how including cold chain depreciation costs dramatically alters the cost results. Because of the extremely high cost of the solar refrigerators in Niassa province, including the depreciation changes the results such that the absolute annual cost is greater in Niassa province. Including cold chain depreciation would change a primary study finding to be the dedicated vaccine logistics system in Cabo Delgado was 23.2% less expensive than the Niassa system on an absolute level: $349,805 per year compared to $455,313 per year. The cost-effectiveness of the two systems also changes to have a greater magnitude with the dedicated vaccine logistics system in Cabo Delgado being significantly more cost-effective, at $5.76 per child vaccinated with DPT-Hep B3 compared to $10.36 per child vaccinated with DPT-Hep B3 in Niassa.

The most significant change by including the cold chain depreciation costs is that the Project to Support PAV logistics system allocates a significantly greater proportion of expenses to the actual cost of vaccines rather than to the distribution system: in the vaccine logistics system in Niassa, the purchase cost of vaccines and syringes comprised only 27% of total distribution system expenses, while in the Project to Support PAV system, they totaled 54% of the vaccine logistics system expenses.

These vast differences in the costs including cold chain depreciation also indicate that investing in cold chain equipment is not always a comprehensive solution to improving immunization coverage rates. While well-performing cold chain infrastructure remains a critical component of immunization services, cold chain capital investment does not inherently guarantee a return on investment. In addressing cold chain needs and considering an investment in equipment, decision makers should examine the ability of the logistics system to support the cold chain and the consequent cost implications.

Appendix E: Estimated Niassa Costs with the Project to Support PAV System

Transport					
	Totals From Data	Entire Province Estimate	Entire Province Estimate	$/dose delivered	Percent of Total Costs
	(one month)	(one month)	(12 months)		
Monthly Costs					
Vehicle Breakdown Cost	$171.75	$171.75	$2,061.00	$0.00	26.39%
Public Transport Usage Cost	$0.00	$0.00	$0.00	$0.00	
Fuel Costs	$1,573.56	$1,573.56	$18,882.71	$0.03	
Vehicle Depreciation	$1,899.59	$1,899.59	$22,795.08	$0.04	
Scheduled Vehicle Maintenance	$1,201.01	$1,201.01	$14,412.14	$0.02	
Insurance Costs	$693.00	$693.00	$8,316.00	$0.01	
Total Transport Costs	$5,538.91	$5,538.91	$66,466.93	$0.11	
Personnel					
Monthly Costs					
Salaries	$689.00	$689.00	$8,268.00	$0.01	10.47%
Per Diems	$1,508.00	$1,508.00	$18,096.00	$0.03	
Total Transportation Personnel Costs	$2,197.00	$2,197.00	$26,364.00	$0.04	
Cold Chain					
Monthly Costs					
Fuel Costs	$924.69	$924.69	$11,096.33	$0.02	10.42%
Costs Recurring Variably					
Refrigerator Breakdown: Labor Costs	$54.73	$54.73	$656.71	$0.00	
Refrigerator Breakdown: Transport Costs	$252.15	$252.15	$3,025.76	$0.01	
Refrigerator Breakdown: All Other Costs	$956.28	$956.28	$11,475.41	$0.02	
Total Refrigerator Breakdown Costs	$1,263.16	$1,263.16	$15,157.88	$0.03	
Total Refrigeration Costs	$2,187.85	$2,187.85	$26,254.20	$0.04	
Vaccines & Supplies					
BCG Vaccine	$1,024.42	$1,024.42	$12,293.03	$0.15	52.72%
DPT-Hep B Vaccine	$2,756.27	$2,756.27	$33,075.28	$0.18	
VAP Vaccine	$3,123.32	$3,123.32	$37,479.81	$0.21	
VAS Vaccine	$809.79	$809.79	$9,717.47	$0.20	
VAT Vaccine	$772.80	$772.80	$9,273.60	$0.10	
0.5 ml Syringe	$2,076.87	$2,076.87	$24,922.50	$0.08	
0.05 ml Syringe	$483.43	$483.43	$5,801.16	$0.10	
5 ml Syringe	$19.57	$19.57	$234.82	$0.04	
Total Vaccine Costs	$11,066.47	$11,066.47	$132,797.68	$1.04	
Total Incremental Cost Over 12 Months					
Total Cost:	$20,990.23	$20,990.23	$251,882.81	$1.24	
Total Number of Children DPT-Hep B3 Vaccinated	4,842	4,842	58,104		
Estimated Cost per Child DPT-Hep B3 Vaccinated	$4.34	$4.34	$4.34		
Total Number of Children Under Age 5	179,892	179,892	179,892		
Total Cost Per Child Under Age 5	$0.12	$0.12	$1.40		
Total Number of Vaccine Doses Delivered	49,862	49,862	598,349		
Total Cost Per Dose Delivered	$1.24	$1.24	$1.24		