OPTIMIZE

Delivering Vaccines

A cost comparison of in-country vaccine transport container options

OPTIMIZE Immunization systems and technologies for tomorrow

PATH World Health Organization

This report was commissioned by Optimize: Immunization Systems and Technologies for Tomorrow, a World Health Organization and PATH collaboration. The report was authored by Kristina Lorenson and Mercy Mvundura, PATH.

Contact information:
Kristina Lorenson
Commercialization Officer, Immunization Technologies
klorenson@path.org

Mail
PO Box 900922
Seattle, WA 98109 USA

Street
2201 Westlake Avenue, Suite 200
Seattle, WA 98121 USA
www.path.org

Suggested citation:
PATH, World Health Organization (WHO). *Delivering Vaccines: A Cost Comparison of In-Country Vaccine Transport Container Options.* Seattle: PATH, WHO; 2013.

This project was funded by a grant from the Bill & Melinda Gates Foundation. The views expressed herein are solely those of PATH and do not necessarily reflect the views of the Foundation.

Cover photo: World Health Organization/Aya Kouamé

PROJECT OPTIMIZE

Delivering Vaccines

A cost comparison of in-country vaccine transport container options

January 2013

TABLE OF CONTENTS

ACKNOWLEDGMENTS

This report was funded by Optimize, a World Health Organization and PATH collaboration, with technical insights and information contributed by Sophie Newland, Joanie Robertson, John Lloyd, Emmanuel Cour, and Mamadou Diallo (PATH); Modibo Dicko (WHO); and Steve McCarney (Solar Electric Light Fund).

ACRONYMS

BCG	bacillus Calmette-Guérin
DTP-HepB-Hib	diphtheria, tetanus, pertussis-hepatitis B-*Haemophilus influenzae* type B vaccine
EPI	Expanded Programme on Immunization
FIC	fully immunized child
PCM	phase-change material
PCV13	13 valent pneumococcal conjugate vaccine
PQS	Performance, Quality and Safety
TT	tetanus toxoid vaccine
WHO	World Health Organization

BACKGROUND

Vaccine supply and delivery systems in developing countries are being tested in new ways as promising new vaccines become available. Technological advances and improved coordinating and funding mechanisms are creating increased access to lifesaving vaccines.

With increasing volumes of vaccines comes increasing demand for expanded cold chain capacity and added pressure on countries to use limited resources efficiently while ensuring sustainable vaccine supply and delivery. In Senegal, for example, vaccine volumes are expected to double when pneumococcal and rotavirus vaccines are added to the routine immunization schedule; introduction is anticipated to occur in 2013 and 2015, respectively. In turn, vaccine transport volumes will rise, requiring larger containers or more frequent trips using current containers to outlying facilities to deliver the vaccines.

Project Optimize, a collaboration between PATH and the World Health Organization (WHO), undertook a cost comparison of five container options for vaccine transport, focusing on Senegal as our case study location. Our goal was to provide insight into existing and future transport options for countries as they work to ensure the integrity of vaccines and identify lower cost methods of transporting them from the national store to subnational facilities. Specifically, we explored transportation from the national level to the regional level.

Table 1 shows the purchase price and physical characteristics of each container option entered as inputs into the cost model. For each container, we factored vaccine volume capacity, durability, and cold life into the cost per liter of vaccine transported. Cold life is defined by WHO in the performance specification for passive cold boxes and vaccine carriers as the time from which frozen icepacks are placed in the container and the lid is closed until the temperature of the warmest point in the vaccine storage compartment first reaches 10°C, at a constant ambient temperature of 43°C. We also outlined specific characteristics of each container, which would be required for implementation, including the need for a forklift, pallet jack, or loading dock. We did not account for this loading equipment, however, in the cost assessment but instead assumed this equipment was already available at the central warehouse and regional facilities.

This cost comparison evaluates the following container options:

- **Dometic RCW25**—a traditional vaccine cold box commonly used in developing countries.[1] This option has the smallest vaccine volume capacity per unit as well as the lowest purchase price and the longest cold life.

Photo: Dometic

- **Aircontainer Big Box**—a large, pallet-based vaccine container with optional wheelbase.[2] Laboratory tests confirm that this container offers very stable temperatures. The WHO Performance, Quality and Safety (PQS) category for this type of container is only recently published (December 2012); therefore, the Big Box has not been qualified. According to the manufacturer, the Big Box without wheels may be lifted mechanically (maximum loaded weight is 204 kg).[3] For the purpose of this analysis, we assume the Big Box with wheels is not stackable.

Photo: Aircontainer

- **Pallet-based international vaccine shipping container**—These containers are made of insulating foam and cardboard integrated on a pallet, and are used by some vaccine manufacturers for large shipments, as they offer a more efficient ratio of product volume to total shipping volume than the smaller styrofoam boxes commonly used for shipping. This option offers greater vaccine volume capacity and cold life durability than most of the other options considered in this cost comparison. The analysis assumes reuse of pallet shippers, which arrive to the central medical stores from global manufacturers. Use of pallet shippers assumes sufficient cold storage space is available at warehouses between transport legs. Reuse of pallet shippers also presents a possible risk of structural failure. The cost of additional cold storage space and the risk of pallet shipper failure beyond four reuses are not included in the comparison because we did not have any data on which to base the assumptions. There are many different pallet shippers; for purpose of this analysis, we are using a common pallet shipper produced by Sofrigam.[4] Current WHO PQS specifications do not include a category for pallet shippers.

Photo: Sofrigam

- **Iveco 16 m^3 refrigerated vehicle or similar size refrigerated vehicle** (authors' unpublished data, 2011)[5]—This option has the highest purchase price per unit as well as the greatest vaccine volume capacity. The high cost of refrigerated vehicles and their tendency to suffer mechanical breakdowns have prevented many developing countries from using this transport method. Current WHO PQS specifications do not include a category for refrigerated trucks.


Photo: Iveco

Table 1. Vaccine container characteristics

Container characteristics	Dometic RCW25 cold box	Aircontainer Big Box	Aircontainer Big Box with wheels	Pallet shipper	Iveco refrigerated vehicle
Vaccine volume capacity (liters)	20.7	130	130	1,574	15,971
Purchase price per unit (US$)	$792	$2,219	$2,219	$0	$95,322
Cargo dimensions (L x W x H meters)	0.710 x 0.550 x 0.490	0.950 x 1.212 x 0.850	0.960 x 1.212 x 0.850	1.260 x 1.025 x 1.240	1.950 x 1.950 x 4.200
Life of container (years)	10	10	10	0.25	10
Transport vehicle					
No. fitting into a single cab four-wheel-drive truck with a canopy	12	1	1	0	N/A
Corresponding vaccine volume	240	130	130	-	N/A
No. fitting into Isuzu Camion	54	12	6	2	N/A

Container characteristics	Dometic RCW25 cold box	Aircontainer Big Box	Aircontainer Big Box with wheels	Pallet shipper	Iveco refrigerated vehicle
or similar vehicle					
Corresponding vaccine volume	1,080	1,560	780	3,148	N/A
Ice packs (0.6 liter)/container	24	16*	16*	32	N/A
Cold life duration at 43°C (hours)	114.9	62.5	62.5	120†	N/A

* Uses ThermoShield coolant packs with phase-change material (PCM) designed to fit the Big Box.

† Manufacturers did not test according to WHO PQS prequalification specifications and therefore duration of cold life at 43°C has not been confirmed.

WHO PQS prequalification requires that containers have a minimum lifespan of 10 years; therefore, we assumed each of these containers will last 10 years, with the exception of the pallet shipper, which may be used for four trips before losing structural integrity.

We also considered transport options for each container choice (except the Iveco refrigerated vehicle, where the container and transport method are integrated). We looked at two standard transport options. The smaller option is a single cab four-wheel-drive vehicle with a cargo area of (L x W x H) 1.35 x 1.12 x 1.04 meters. The larger option is an Isuzu Camion truck or similar vehicle with a cargo area of 4.10 x 1.71 x 1.73 meters.[6,7] In each case, we took into account the vehicle purchase price and fuel efficiency and used these to estimate the depreciation, fuel, and maintenance costs.

Case study: Senegal

We evaluated vaccine transport scenarios in Senegal across three possible delivery routes (Figure 1):

- A separate delivery schedule for each of the 14 regions.
- A two-axis model using a north-south route plus the Dakar region (the Dakar region had a separate delivery because it serves the largest population but is located less than 5 km from the national store).
- A four-axis model using a north-south-east-west route plus the Dakar region.

Figure 1. Transport routes in Senegal

Dakar to each region

Dakar region plus north-south route

Dakar region plus north-south-east-west route

Using regional population data, the vaccine specifications, the wastage and coverage rates, and the Expanded Programme on Immunization (EPI) schedule data shown in Table 2, we estimated transport volumes for current and future vaccine schedules in Senegal.[8,9] We estimated the current annual volume per region for the routine vaccines (bacillus Calmette-Guérin [BCG]; polio; diphtheria, tetanus, pertussis-hepatitis B-*Haemophilus influenzae* type B [DTP-HepB-Hib]; measles; tetanus toxoid [TT]; and yellow fever) as well as new vaccines to be added in the future (pneumococcal conjugate and rotavirus vaccines). Our scenarios assume a quarterly delivery schedule for vaccines shipped from Dakar to outlying regional warehouses.

Table 2. Vaccine specifications, wastage, and coverage rates and EPI schedule in Senegal

Vaccines	Doses per FIC	National coverage	Doses per vial	Wastage rate	Volume (secondary packaging)/ dose (cm^3)	Volume of diluent (cm^3)	Price/dose (US$)
BCG	1	90%	20	50%	1.2	0.7	0.10
Polio	4	90%	10	10%	2.0		0.19
DTP-HepB-Hib	3	90%	1	5%	12.9		3.64
Measles	1	80%	10	25%	3.5	4.0	0.24
TT	2	80%	10	10%	3.0		0.09
Yellow fever	1	80%	10	25%	2.5	3.0	0.83
PCV13	3	80%	1	5%	13.5		7.00
Rotarix	2	80%	1	5%	17.3		5.00

BCG = bacillus Calmette-Guérin vaccine; DTP-HepB-Hib = diphtheria, tetanus, pertussis-hepatitis B-*Haemophilus influenzae* type B vaccine; FIC = fully immunized child; PCV13 = pneumococcal conjugate vaccine; TT = tetanus toxoid vaccine

RESULTS

We divided our results into two parts: one for the current routine immunization schedule and the other for routine immunizations plus the new pneumococcal conjugate vaccine (PCV13) and the rotavirus vaccine (Rotarix), which will be introduced into the schedule in the near future. As mentioned before, this analysis assumes quarterly delivery to the regions.

Current routine immunizations

For the current routine immunizations, the refrigerated truck has the lowest overall cost per liter of vaccine transported, ranging from $0.29 to $0.30 per liter, depending on the delivery route used (Table 3). Note that developing countries rarely use refrigerated vehicles for vaccine delivery because of their high upfront cost and maintenance requirements.

Looking at the remaining four options, when vaccine delivery occurs using the single cab four-wheel-drive truck, the lowest-cost choice is the use of cold boxes with individual trips to each region at a cost of $0.98 per liter. The next best option is the Aircontainer Big Box making individual trips to each region at a cost of $1.07 per liter. The pallet shipper cannot fit into the single-cab four-wheel drive truck; therefore, if this vehicle is the only available transport option, the pallet shipper cannot be used.

Using the Isuzu Camion truck, the least cost option is the pallet shipper using a four-axis delivery route, with a cost of $0.28 per liter. The next best option using the Camion truck is the Aircontainer Big Box with or without wheels making individual trips from the national store to each region at a cost of $0.44 per liter. This assumes an investment is made in only six containers. When individual trips are made to each region, there is enough transport capacity to most regions when using six Big Boxes.

If a refrigerated truck or pallet shipper is not available, routing to each region independently offers lower costs per liter (Figure 2). With the two- and four-axes delivery route plan, the containers cannot accommodate all the volume of vaccines for the regions in the route, so they have to make multiple trips to get the required volumes to the regions. This makes this route plan relatively inefficient when compared to the others.

Figure 2. Total container and transport cost per liter routine vaccines delivered by route plan

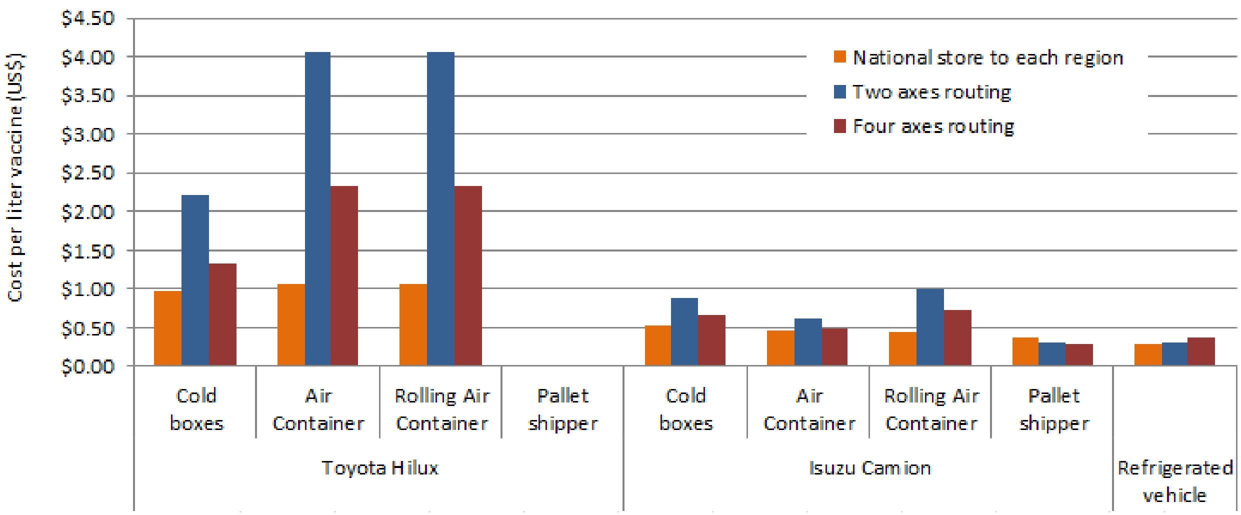

Table 3. Analysis results for routine immunization

	Dometic RCW25 cold box	Aircontainer Big Box with or without wheels	Pallet shipper	Dometic RCW25 cold box	Aircontainer Big Box	Aircontainer Big Box with wheels	Pallet shipper	Iveco refrigerated vehicle*
	Singe cab four-wheel-drive truck			Isuzu Camion or similar vehicle				
Capital costs								
Containers	$9,499	$2,219	$0	$42,745	$26,628	$13,314	$0	$0
Vehicles	$25,000			$36,154				$95,322
Container deprecation	$1,114	$260		$5,011	$3,122	$1,561	$0	$0
Routine vaccines								
Transport costs								
National store to each region	$32,176	$35,963		$13,008	$12,806	$13,439	$12,797	$9,830
Two axes	$73,912	$137,183		$25,121	$17,851	$32,404	$10,569	$10,134
Four axes	$44,176	$78,643		$17,164	$13,280	$23,539	$9,394	$13,071
Total costs for containers and transport by route plan								
National store to each region	$33,289	$36,224		$18,019	$15,928	$15,000	$12,797	$9,830
Two axes	$75,025	$137,444		$30,132	$20,973	$33,965	$10,569	$10,134
Four axes	$45,289	$78,903		$22,175	$16,402	$25,100	$9,394	$13,071
Transport and container costs per liter transported by route plan								
National store to each region	$0.8	$1.07		$0.53	$0.47	$0.44	$0.38	$0.29
Two axes	$2.22	$4.06		$0.89	$0.62	$1.00	$0.31	$0.30
Four axes	$1.34	$2.33		$0.66	$0.49	$0.74	$0.28	$0.39

*Include depreciation, fuel, and maintenance costs. Personnel costs and per diems not included in the analysis.

Routine plus new immunizations

In this scenario, vaccine volume is doubled as new vaccines are introduced, but transport costs rise at a lower rate (Figure 3 and Table 4). Thus, the cost per liter of vaccine transported falls, and costs decline more for the route plan where there is a separate delivery to each region using either the Isuzu Camion or the refrigerated vehicle. With the larger vehicles the container space available for vaccine storage of routine vaccines was not being fully utilized, so additional volume can be transported on the same trip without need for additional trips. Moreover, when new vaccines are added to the schedule, the delivery of vaccines to each region individually is the least cost option, regardless of vehicle type, since vehicles will only be able to accommodate the routine and new vaccine volumes for a single region.

Once again, the refrigerated truck option, if available, offers the least cost option for transporting large volumes of vaccine. Costs using this method range from $0.11 to $0.15 per liter, depending on the delivery route plan.

The lowest-cost option using the single cab four-wheel-drive truck is the use of cold boxes at a cost of $0.85 per liter, but note that multiple trips have to be made. These average six trips per quarter for delivery to the regions outside of Dakar, and as many as 13 trips to larger regions such as Thies.

Using the Isuzu Camion truck, the least cost option is the pallet shipper, with a cost of $0.14 per liter. The cost of the pallet shipper using the four-axis delivery route is only slightly higher at $0.19 per liter. If the pallet shipper option is not available, the next most cost-effective choice using the Camion truck is the Aircontainer Big Box without wheels at a cost of $0.20 per liter transported, which would provide enough capacity for one delivery per quarter to most regions.

We also examined the effect of adding the new human papillomavirus vaccine and found similar cost scenarios, with the exception that there are additional cost savings when using refrigerated trucks.

Figure 3. Total container and transport cost per liter routine vaccines plus PCV13 and rotavirus vaccines delivered by route plan

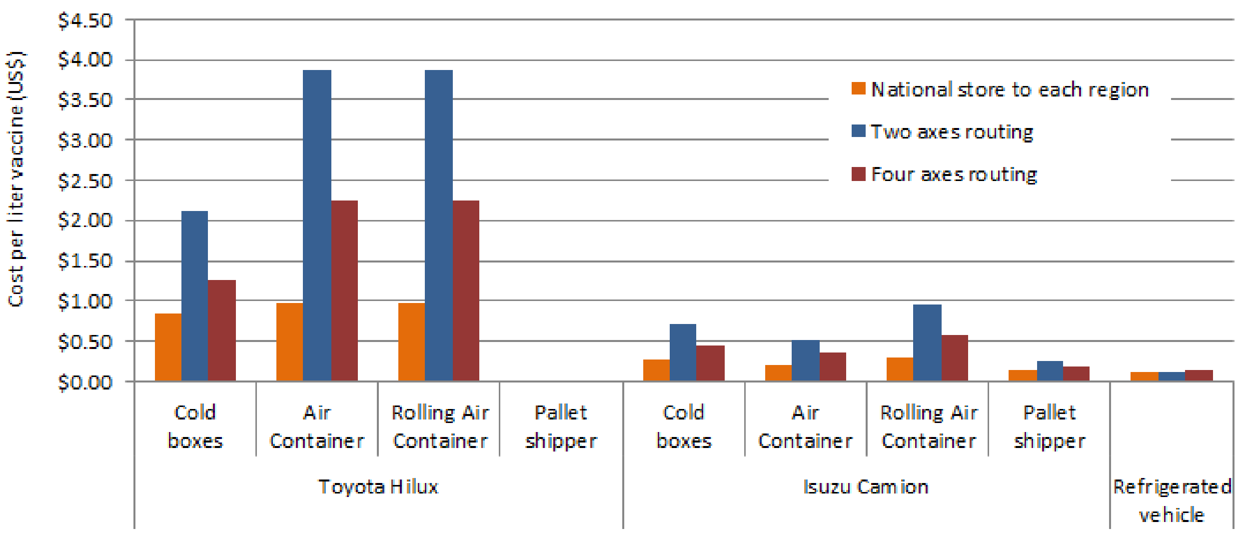

Table 4. Analysis results for routine immunization plus pneumococcal conjugate vaccine (PCV13) and rotavirus vaccine

	Dometic RCW25 cold box	Aircontainer Big Box with or without wheels	Pallet shipper	Dometic RCW25 cold box	Aircontainer Big Box	Aircontainer Big Box with wheels	Pallet shipper	Iveco refrigerated vehicle*
	Single cab four-wheel-drive truck			Isuzu Camion or similar vehicle				
Capital costs								
Containers	$9,499	$2,219	$0	$42,745	$26,628	$13,314	$0	$0
Vehicles	$25,000			$36,154				$95,322
Container deprecation	$1,114	$260		$5,011	$3,122	$1,561	$0	$0
New vaccines (routine + PCV13 and rotavirus)								
Transport costs								
National store to each region	$74,092	$85,845		$19,020	$14,201	$25,153	$12,806	$9,830
Two axes	$186,415	$341,439		$57,525	$42,959	$82,633	$21,835	$10,134
Four axes	$110,280	$197,689		$35,540	$28,288	$50,203	$17,164	$13,071
Total costs for containers and transport by route plan								
National store to each region	$75,206	$86,105		$24,031	$17,323	$26,714	$12,806	$9,830
Two axes	$187,528	$341,699		$62,536	$46,081	$84,194	$21,835	$10,134
Four axes	$111,394	$197,949		$40,551	$31,409	$51,764	$17,164	$13,071
Transport and container costs per liter transported by route plan								
National store to each region	$0.85	$0.97		$0.27	$0.20	$0.30	$0.14	$0.11
Two axes	$2.12	$3.86		$0.71	$0.52	$0.95	$0.25	$0.11
Four axes	$1.26	$2.24		$0.46	$0.35	$0.58	$0.19	$0.15

*Include depreciation, fuel, and maintenance costs. Personnel costs and per diems not included in the analysis.

RECOMMENDATIONS

Looking only at the cost figures from our analysis, the refrigerated truck offers the most cost-effective option for vaccine delivery in both scenarios studied, with costs depreciated over the life of the vehicle at or below those of the other four delivery options. If capital is available, a second refrigerated truck could be purchased in case the primary vehicle breaks down. However, readers are cautioned that there are a number of additional costs and risk associated with refrigerated trucks that do not exist with the other options in this comparison analysis. First, the required upfront investment costs are significant, with each vehicle costing more than $95,000. In addition, the costs associated with potential breakdowns of refrigerated vehicles, which are not included in the cost estimates comparison, may be sufficiently high and convincing that other transport options may work as well or better. Studies in sub-Saharan Africa have demonstrated the need for spare parts and committed maintenance of vaccine transport vehicles to ensure the fleet is available and repairable at all times.[10] This analysis did not account for the additional costs associated with spare parts and available repair personnel.

Furthermore, use of refrigerated trucks in one country illustrated that vaccines were transported without additional insulated packing. Thus, any breakdown in the truck or transfer of products from refrigerated truck to warehouse or another vehicle would place the vaccines at risk of degradation.[11] The use of refrigerated trucks should continue to require cold packing provisions to protect vaccines in emergency situations. These additional costs for cold boxes or other insulated containers may also need to be factored into the overall cost of using refrigerated vehicles.

If a standard single cab four-wheel-drive vehicle is the only available transport option, the least cost container choice is the use of cold boxes for delivery of both routine and new vaccines, when up to 360 liters of vaccines is transported in a single trip. The overall costs per liter of vaccine delivered using the four-wheel-drive vehicle are substantially higher than using the Camion truck or the refrigerated vehicle because of the limited number of containers and corresponding volume of vaccine that can be transported on each trip.

Using an Isuzu Camion truck or similar vehicle, the least cost option is the reuse of a pallet-shipper for delivery of both routine and new vaccines. The pallet shipper poses a unique advantage over other delivery options because it does not require additional container costs since we assume the reuse of the pallet received via international transport from the manufacturer. Thus, the pallet shipper is the least cost option, followed by the Aircontainer Big Box. It is important to note that the reuse of a pallet shipper still needs to be tested for vaccine delivery in-country to ensure it maintains substantial durability and performance. Pallet shippers are often broken down and reused for transporting food or building materials, which could place their structural integrity in question. This could pose a risk for countries using pallet shippers for vaccine transport as it may be difficult to determine their sturdiness. We recommend additional field testing to understand the extent of reuse and the creation of uniform standards for reuse of pallet shippers.

This cost comparison provides a starting point for country vaccine programs weighing transport options in the face of increasing vaccine volume. Specific country transport requirements will be affected by vaccine introduction policies and timelines, geography, and other factors. Before making a final decision, we recommend that country health officials assess their future vaccine capacity requirements, evaluate distribution scenarios, and test pilot routes to compare performance, security, and cost.

REFERENCES

1. WHO. Dometic RCW25 [fact sheet]. Geneva: WHO; 2010. Available at: http://tinyurl.com/c592a58. Accessed October 1, 2012.

2. Big Box page. Aircontainer website. Available at: http://tinyurl.com/a3knyyp. Accessed October 1, 2012.

3. Danish Technology Institute. *Test Report: Aircontainer Big Box Polypropen Container*. Denmark: Danish Technology Institute; 2011.

4. Sofrigam. Product information sheet, Frizbox® 1890/MIP page. Sofrigam website. Available at: http://www.sofrigam.com/the-pallet-shipper-frizbox. Accessed October 1, 2012.

5. Cooling box truck dimensions page. Alibaba website. Available at: http://tinyurl.com/ac3sszg. Accessed October 1, 2012.

6. Land Rover forum page, Land Rovers Only website. Available at: http://www.landroversonly.com/forums/f40/discovery-ii-cargo-area-dimensions-not-area-29909/. Accessed October 1, 2012.

7. McCarney S. *Analysis of Equipment Needs: Senegal Transport Containers and Senegal*. Seattle: PATH; 2011.

8. Garnett A. *Vaccine Packaging Study*. Seattle: PATH; 2012.

9. Product menu for the UNICEF vaccines supplied by GAVI page. UNICEF website. Available at: www.unicef.org/supply/files/Product_Menu_March_2012.pdf. Accessed February 1, 2012.

10. Apt Associates, et al, Transport in primary healthcare: a study to determine the key components of a cost effective transport system to support the delivery of primary health services, unpublished study, Feb 2001.

11. PATH, World Health Organization, Health Systems Research Institute, Mahidol University. *An Assessment of Vaccine Supply Chain and Logistics Systems in Thailand*. Seattle: PATH; 2011.