

## Building next-generation vaccine supply systems

### SUPPLY CHAIN MODELING AND OPTIMIZATION

#### Built for an earlier time

With global vaccine coverage at 85 percent, it is easy to take for granted the supply systems that move temperature-sensitive vaccine products from manufacturing facilities to some of the world's most remote populations.<sup>1</sup> For more than 30 years, ministries of health have maintained logistics systems that receive, store, transport, and refrigerate vaccines so they are available where they are needed. These vaccine supply chains have not been perfect. In many countries, half of all vaccine doses are never administered and many more are wasted due to accidental freezing, heat exposure, expiry, and other mishaps.<sup>2</sup> Nevertheless, existing vaccine supply chains have generally been able to cope with the six traditional vaccines in the Expanded Programme on Immunization (EPI).<sup>3</sup>



PATH/Satvir Malhotra

*The value and volume of newer vaccines put pressure on vaccine programs to reduce wastage and improve the efficiency of supply chain systems.*

#### New vaccines warrant new systems

Advances in vaccine development have expanded the number of lifesaving vaccines now available to developing countries, which has changed the logistics equation entirely. As antigens such as pneumococcal, rotavirus, and *Haemophilus influenzae* type b become available to countries, they will increase the volume of products that need to be stored, transported, refrigerated, and tracked. The total volume of vaccines to be managed in many developing countries is expanding as much as five times as

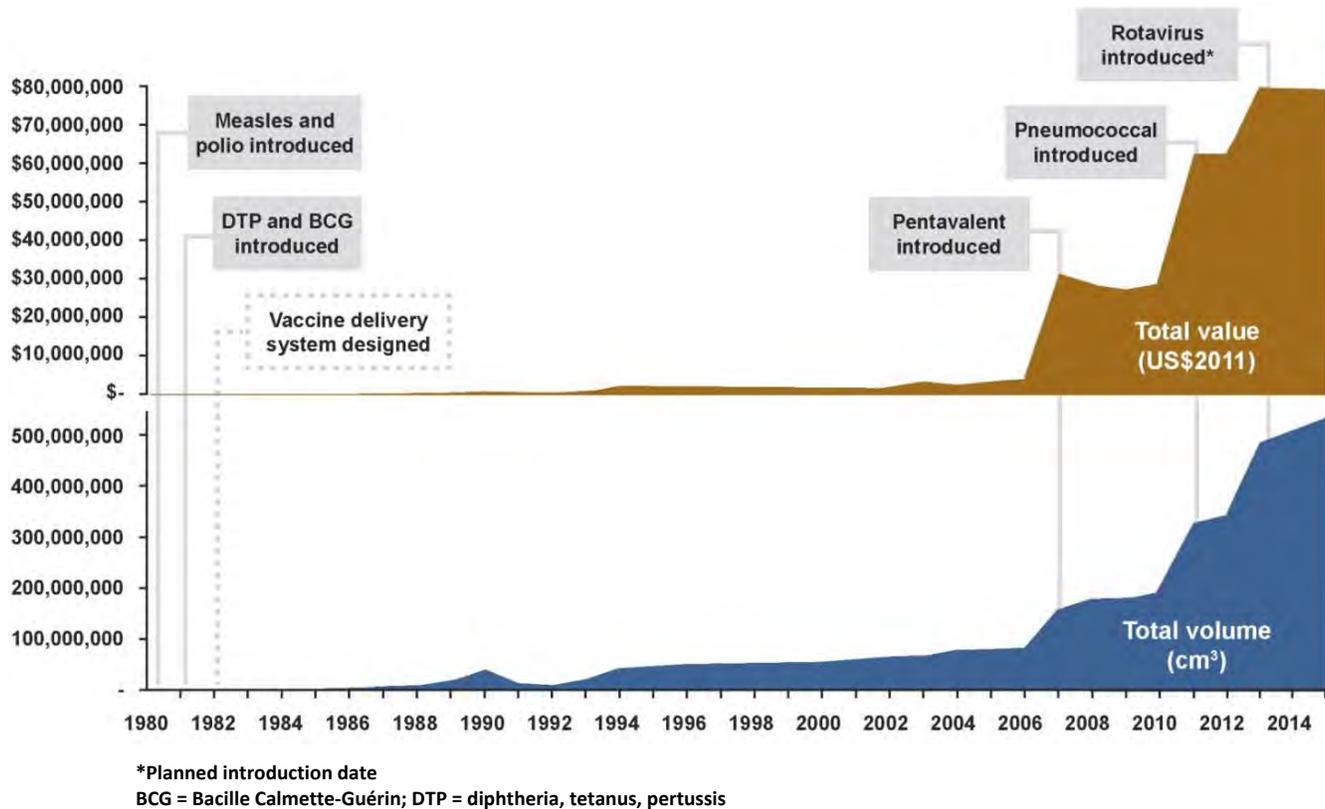
<sup>1</sup> Global vaccine coverage is estimated by tracking the percentage of children receiving the third dose of diphtheria-pertussis-tetanus vaccine. *World Health Organization (WHO) and United Nations Children's Fund (UNICEF) coverage estimates 1980–2010, July 2010, 2011 revision.*

<sup>2</sup> WHO. *Monitoring Vaccine Wastage at Country Level: Guidelines for Programme Managers.* Geneva: WHO Department of Vaccines and Biologicals; 2005. Available at: <http://www.who.int/vaccines-documents/DocsPDF05/www811.pdf>.

<sup>3</sup> The six traditional vaccines in the Expanded Programme on Immunization protect against diphtheria, pertussis, tetanus, polio, measles, and tuberculosis.

newer vaccines are introduced, with further increases expected when additional vaccines, such as those for malaria are introduced later in the decade (see Figure 1).<sup>4</sup>

**Figure 1.** Cumulative value and volume of vaccines used in routine childhood vaccinations in Ethiopia<sup>4-6</sup>



The cost of new vaccines is also significantly higher than traditional vaccines—in some cases more than 50 times higher.<sup>5</sup> Figure 1 shows the cumulative volume and value of vaccines introduced (and planned for introduction) in Ethiopia between 1980 and 2014.

In the past, a power outage, faulty refrigerator, or flat tire might have resulted in a US\$100 loss of traditional vaccines. The same mishap now could result in a loss of US\$5,000 worth of newer vaccines. In this environment, wastage rates of 50 percent can translate to an enormous loss of scarce financial resources.

<sup>4</sup> WHO. *Vaccine Volume Calculator*. Geneva: WHO Immunization Service Delivery and Accelerated Disease Control Programme. Available at: [http://www.who.int/immunization\\_delivery/systems\\_policy/logistics/en/index4.html](http://www.who.int/immunization_delivery/systems_policy/logistics/en/index4.html).

<sup>5</sup> UNICEF Supply Division. Vaccine price data page. UNICEF website. Available at: [http://www.unicef.org/supply/index\\_57476.html](http://www.unicef.org/supply/index_57476.html). Accessed May 9, 2012.

<sup>6</sup> Sabot O, Yadav P, Zaffran M. *Maximizing Every Dose and Dollar: The Imperative of Efficiency in Vaccine Delivery*. Seattle: National Bureau of Asian Research; 2011. Impact and Innovation Series.

## Repairing old systems, visualizing new ones

The need for robust and efficient vaccine supply systems has focused much-needed attention on diagnostic and management tools for measuring and systematically improving supply chain performance in individual countries. One such tool, the Effective Vaccine Management (EVM) quality improvement process, is available to help countries build vaccine supply chains based on established quality management principles. The assessment part of the EVM process consists of 562 questions grouped under 9 headings. Countries applying for new vaccines from the GAVI Alliance are required to embark on the EVM process, and as of May 2012, more than 50 countries have completed their first assessments.<sup>7,8</sup>

The EVM process has been useful for diagnosing problems and making repairs to existing supply systems. However, the EVM process alone does not compel countries to redesign their supply chains. Most decision-makers will need strategic guidance, funding, and a compelling rationale to change the policies, systems, and personnel that shape the supply system.

Building on momentum generated through the EVM process, several countries have had an opportunity to experiment with a powerful modeling software tool developed by the Vaccine Modeling Initiative at the University of Pittsburgh. This software, called HERMES (Highly Extensible Resource for Modeling Supply Chains), can rapidly generate a simulation model of any supply chain, allowing national decision-makers to simulate operational, structural, policy, procurement, technological, and managerial changes to the supply chain and to visualize the impact on cost and various operational and immunization measures.

A HERMES-generated simulation model can serve as a virtual laboratory for decision-makers trying to answer difficult questions related to the following:

- **Introducing new technologies**—What would be the impact of replacing products or introducing new products and technologies (e.g., new vaccine products, monitoring devices, solar refrigerators, passive cooling devices)?
- **Choosing among products**—How do different vaccine characteristics affect our ability to meet program objectives (e.g., 10-dose versus single-dose vials, liquid versus lyophilized, intradermal versus oral)?
- **Making personnel decisions**—What are the effects of changing personnel at different locations and on different routes?
- **Altering supply chain structure or policies**—How do operational decisions affect performance and cost (e.g., numbers of storage units, shipping frequency, adding or removing storage levels, personnel, procurement policies)?
- **Selecting transport vehicles and policies**—How would different transport and storage methods change performance (e.g., outsourced transport, integrated transport and storage with other supply chains, streamlined transport routes, last-mile delivery)?

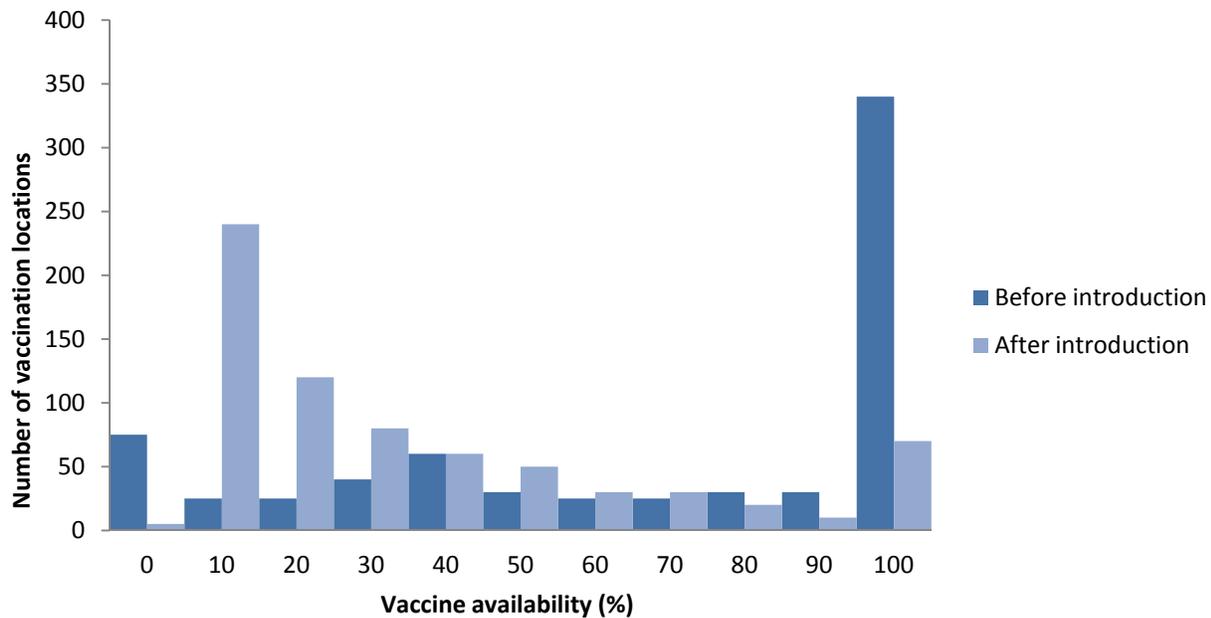
---

<sup>7</sup> Lee BY, Assi TM, Rajgopal J, et al. Impact of introducing the pneumococcal and rotavirus vaccines into the routine immunization program in Niger. *American Journal of Public Health*. 2012;102(2):269–276.

<sup>8</sup> Lee BY, Assi TM, Rookkapan K, et al. Replacing the measles ten-dose vaccine presentation with the single-dose presentation in Thailand. *Vaccine*. 2011;29(21):3811–3817.

The answers to these questions can feed into larger questions about how vaccine supply systems can be optimized to maximize vaccine availability and how to invest in systems for efficient use of resources. For example, Figure 2, which is based on HERMES data, demonstrates how the introduction of rotavirus and pneumococcal vaccines would impact vaccine availability at each immunization location in Niger without subsequent improvements to the system.

**Figure 2.** Predicted vaccine availability at the health care level in Niger before and after introduction of pneumococcal and rotavirus vaccines



### Flexibility and functionality

The HERMES simulation model is flexible enough to represent every storage location, refrigerator, freezer, vehicle, staff person, vaccine/diluent vial, and vaccine device in any supply chain. Collecting the data and populating the model is time consuming, which is why additional data collection activities need to be conducted along with an EVM or similar cold chain inventory assessment.

Once the model is populated with country-specific data, millions of different vaccine doses can flow through the model simultaneously, just like a real supply chain. The simulation model also includes virtual people that arrive at designated immunization locations on immunization days. The model assumes that if the correct vaccine products are available at the immunization session, then the person arriving at the immunization session is successfully immunized. If the vaccine is not available, then the model counts the person as a missed vaccination opportunity.

Project Optimize developed a vaccine supply chain costing tool using Microsoft Excel that can translate relevant operational measures into economic measures of interest (e.g., cost per dose administered, cost by location, and cost by activity).

The range of questions that the HERMES-generated model can address depends on the amount and quality of input data and analytical skills to interpret the scenarios; also modeling certain intangibles,

such as the value of information systems, human resource development, and devices that improve safety, may require certain assumptions.

### **Pilots and future implementation**

The HERMES simulation model has been used in Niger, Senegal, Thailand, and Vietnam. A pilot currently underway in Benin, however, will go significantly beyond previous applications of the HERMES model to date.

The Benin pilot aims to achieve three outcomes:

1. Determine how quantitative data collected alongside the EVM assessment can be used to populate the HERMES model.
2. Implement a country-owned, evidence-based decision-making process for a newly designed vaccine supply chain in Benin.
3. Generate best practices from the data collection, modeling, and decision-making process that other countries can use to redesign their supply chains.

To achieve these outcomes, a project advisory group led by Agence de Médecine Préventive (AMP) has been established to support the project design and implementation. Group members include senior staff from AMP, the Bill & Melinda Gates Foundation, PATH, the United Nations Children's Fund, the World Health Organization, and the Vaccine Modeling Initiative at the University of Pittsburgh.

To ensure country ownership, assessment, and modeling activities are closely coordinated with the Ministry of Health and Interagency Coordinating Committee for EPI in Benin, several workshops with all stakeholders are scheduled to take place in mid-2012 to walk through the assessment and scenario-modeling process.

Ultimately, the goal is to demonstrate how countries can rebuild vaccine supply chain systems to more effectively and efficiently handle the volume and value of newer vaccines.

### **For more information**

Contact [Optimize.WHO@path.org](mailto:Optimize.WHO@path.org) or [hermes-info@psc.edu](mailto:hermes-info@psc.edu).

May 2012

