# System Design: Repair or Replace

## Vaccine Supply Chains: *Reaching the Final 20* Policy Paper Series

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VillageReach

Starting at the Last Mile

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## Policy Series Overview

We are mid-way through the *Decade of Vaccines*, marking a period of significant activity to prevent millions of deaths through more equitable access to vaccines. Today, more than 80% of children around the world receive a complete routine of life-saving vaccines during their first year of life. The *Decade of Vaccines* was established to bring attention to the importance of reaching that final 20% of children without access to these life-saving vaccines. This decade is bearing witness to many exciting efforts to strengthen routine immunization, accelerate control of vaccine-preventable diseases, and introduce new and improved vaccines.

To a large extent, the evaluation of this decade's success will be based on the degree to which vaccines reach the people who need them. A strong end-to-end supply chain should adapt to the resource constraints of these communities to ensure that delivery is complete: from the point of production of the vaccine to the point of immunization.

This policy series considers the different components of the supply chain, addresses the challenges faced at the last mile for distribution, and presents examples of innovative approaches to address those challenges. This third paper in the series focuses on the role of system design and how key supply chain components fit together in the most effective manner.

## VillageReach Overview

VillageReach has worked for more than a decade to develop, test, and refine system innovations to improve the performance of in-country vaccine supply chains. Working closely with the Ministry of Health in Mozambique and with support from the Bill & Melinda Gates Foundation, the *Final 20 Project* (designed to reach the final 20% of children without access to vaccines) is building a sustainable model of innovative supply chain design, enhanced data collection and reporting, and public-private partnerships to improve the vaccine supply chain.



To address the unique challenges of last mile distribution, VillageReach is engaged in a multi-year program in Mozambique to improve the performance of the vaccine supply chain, focusing on rural communities that represent over 50% of the country's population. The approach – *the Dedicated Logistics System (DLS)* – was developed in collaboration with provincial governments and the Mozambican organization *Fundação para Desenvolvimento da Comunidade* (FDC). The DLS uses task shifting, level jumping, dedicated resources, and service delivery-level data to improve vaccine supply chain effectiveness and efficiency.

## Requirements at the Last Mile

### The Role of System Design

System design is the blueprint of the architecture, components, processes, and operations of a supply chain. In other words, the design includes all the parts of the supply chain and how they fit together and interact. As with any system, the design of a supply chain is critical. Poor design can severely limit a supply chain and inhibit optimization as there is only so much one can improve within the confines of a particular design. Conversely, good design can make a supply chain more flexible and facilitate ongoing improvement. When a supply chain is not functioning to expected levels, a key question is whether the design can be improved with only minor repair or should be completely replaced. Often it is impossible to improve a supply chain beyond a certain degree by mere repair; changing and replacing its system design may realize more efficiencies.

System design must consider all components of the supply chain and determine how the components fit together and interact. The different components of processes, data, equipment, people, funding, and political will dynamically interact with each other. Changing one component, such as increasing equipment availability, may change other components, such as increasing the number of people involved or the data required to monitor performance. As such, designing the appropriate system must consider all components, how they interact and complement each other, and their adaptation to the particular context.

A key aspect of developing a design is achieving strategic fit by first determining what functions the supply chain must perform and then developing a design that best serves this purpose. For the country-level vaccine supply chain, the design of a system should bring agility, flexibility, responsiveness, and efficiency in ensuring vaccines are available at all immunization posts. A good supply chain design can facilitate its ongoing improvement or optimization.

On the other hand, a design that does not adequately fit its purpose can severely limit a supply chain and inhibit its ongoing optimization. A poorly functioning supply chain can lead to underperformance with stock-outs of vaccines, redundancies in actions, and the inevitable ad hoc efforts to attempt to fill in the gaps where the supply chain is not performing. In this situation, a key question is whether one of the components of the system can be adjusted or repaired to improve performance or if the design itself needs to be changed and replaced. Simply increasing the availability of vehicles or adding additional health workers, for example, may not have the desired impact if those changes are made to a system that is not appropriate for current requirements and operating conditions.



## Challenges at the Last Mile

Since vaccines were first introduced at scale in low-income countries more than 35 years ago, conditions and circumstances have evolved. Population and birth rates have changed; new vaccines have been and will continue to be introduced; currency and politics fluctuate; and new technologies and supply chain practices are constantly being developed. Because of these frequent changes, any new, appropriate system design will become an old, inadequate design over time. These old designs aren't bad; it may simply be time to take advantage of new circumstances and opportunities to find efficiencies and replace the old system with a new system with a modern design that is more appropriate for current needs.

The original expanded program on immunization (EPI) supply chain provides a practical example of this principle (Figure 1). The system's multiple tiers of storage and administration match the basic government administrative tiers; for example: a national warehouse, provincial warehouses, district warehouses, and health facilities where vaccines are administered. A paper-based reporting system initiates the replenishment process for vaccines and related supplies from the health facilities up through the administrative tiers which then triggers delivery of vaccines and supplies down through each of the administrative tiers and finally to the health facilities.

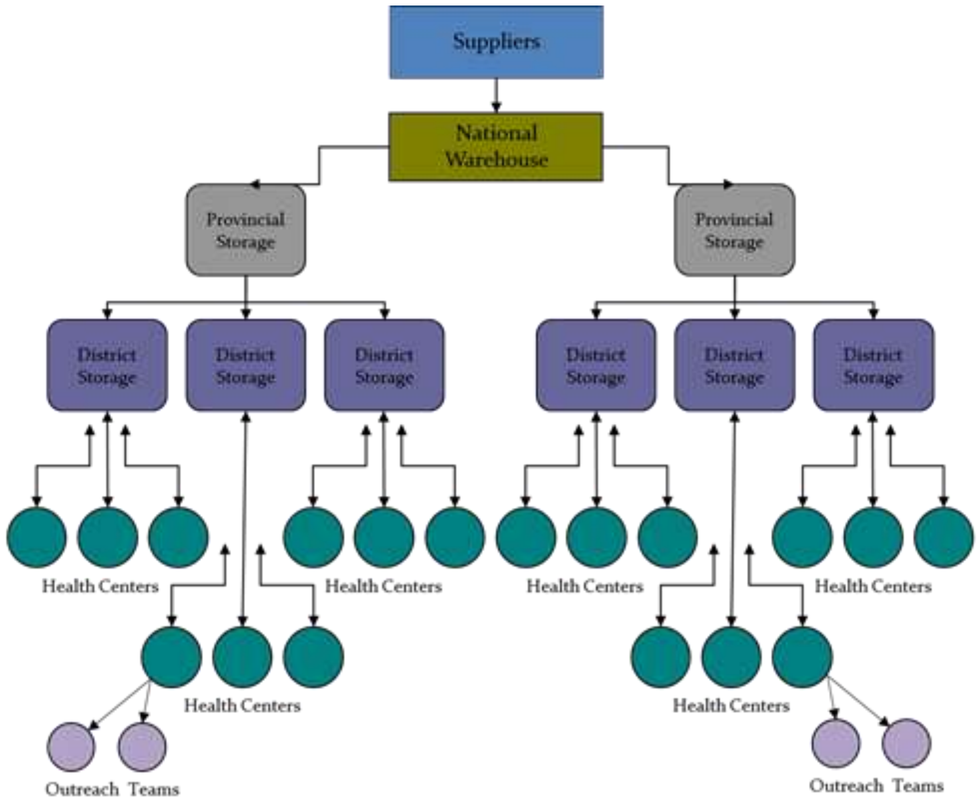


**Figure 1: Common multi-tiered vaccine supply chain**

*The arrows indicate the flow of vaccines, which often occurs in an ad-hoc way due to lack of resources, relying on health workers going to district storage facilities to pick up vaccines.*



This multi-tier distribution system design requires each level of the supply chain to perform various tasks. It requires cold chain storage capacity at each tier sufficient to handle the volume of inventory passing through to each of the levels below that tier, as well as sufficient vehicles to complete the distribution cycle. Adequate and qualified personnel are required at each tier to handle various logistics tasks. For example, at the health facility, health workers are responsible for cold chain monitoring, inventory management, and submitting monthly reports that trigger requisitions. District, provincial and national level workers must perform those tasks as well as managing periodic distributions to their respective next lower level. Finally, sufficient and regular financial resources are necessary at the district, provincial and national levels to maintain cold chain and other assets and perform distribution activities.

Originally created when broad-based vaccine programs were first introduced in low-income countries, this system was designed to overcome the challenge of unknown demand by putting high levels of inventory into the system. While this approach is able contain the incidence of stock-outs by simply pushing more inventory into the supply chain, it results in high levels of wastage, which was not seen as a significant problem given the historically low cost of vaccines. The logistics and management tasks to operate the system are relatively simple, limiting the need for highly trained staff. The system can also operate with a poorly functioning, rudimentary paper-based information system as it only needs periodic consumption data to replenish the various storage locations back up to their respective minimum inventory levels on a scheduled basis. This design was a good choice for the first national immunization program in low-income countries.

Like any system design, the limitations of this system design are exposed when it is subjected to changing conditions and requirements as has happened since vaccines were first introduced. Different components of the system are now being stressed due to these changing conditions and requirements. These challenges are well known:[1] requisitions filled based on poor quality data; a chronic shortage of health workers; inadequate vehicles for distribution of commodities; poorly functioning cold chain; and funding flows not available at the tier in the system where they are needed. The design's weaknesses are more prevalent at the district level where the number of delivery locations and required transactions, equipment and personnel to be supported rises exponentially.[2,3] With the high cost and increased volume of new vaccines, excessive wastage and long inventory hold times, the current system design will face significant challenges. These challenges require more than another patch on an old system design; a new, modern approach is required.

The process of reviewing and potentially revising a supply chain's design is an on-going and natural process that should occur periodically. Absent periodic system design evaluations, supply chain performance and optimization will degrade due to two key factors. First, any design over time will struggle to meet the accumulation of changing requirements and operating conditions. Personnel managing the supply chain will introduce a number of creative coping mechanisms or ad-hoc approaches to extend the life of and compensate for growing deficiencies of the existing system design. Eventually, though, even these measures will fail to accommodate new requirements and a changing environment. Second, it is difficult to introduce new supply chain innovations if the system's design cannot be reconsidered from time to time.



System design work seeks to overcome those factors by exploring various alternatives, such as:

- reducing or adding to the number of intermediate storage levels in a supply chain;
- changing the capabilities, capacity, locations, and/or functioning of storage facilities, for example, through creating regional distribution hubs;
- altering the transportation routes (e.g., hub and spoke versus loop routing);
- outsourcing specific functions, such as fleet management or cold chain equipment maintenance to private or parastatal organizations;
- consolidating and/or reallocating responsibilities for various supply chain functions amongst available personnel;
- changing the manner in which day-to-day decisions are made based on the introduction of new information systems or different key performance indicators (KPIs); and
- evaluating the potential to integrate specific supply chain functions with other health commodity supply chains or merge data collection and management information systems.

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[1] Zaffran M, Vandelaer J, Kristensen D, et al. The imperative for stronger vaccine supply and logistics system. Vaccine. 2013, 31S.

[2] VillageReach. District logistics capacity study: examining the capacity of 53 districts in Mozambique to carry out logistics and supply chain activities. April 2013.

[3] VillageReach. Evaluation of health system transport capacity and demand: Mozambique case study. June 2014.

## Promising Practices for the Last Mile

### The DLS Approach

Mozambique offers an excellent example of the benefits of developing, testing and implementing a new system design. In four provinces in Mozambique, the Provincial Directorates of Health (DPS) asked the tough questions about their system design and reconfigured the components of the supply chain to optimize and find efficiencies. The result, the Dedicated Logistics System (DLS), uses transport loops, level jumping, direct data collection and utilization, and dedicated personnel (field coordinators) to create a more efficient vaccine supply chain. The components of the supply chain are the same; they have simply been rearranged and configured to fit the new circumstances for each of these provinces. With ten years in one province and three years in three additional provinces, the evidence of improved system performance with the DLS is clear with stock-outs of vaccines consistently less than 10%, improved vaccine coverage rates, and cost efficiencies documented.[4,5]

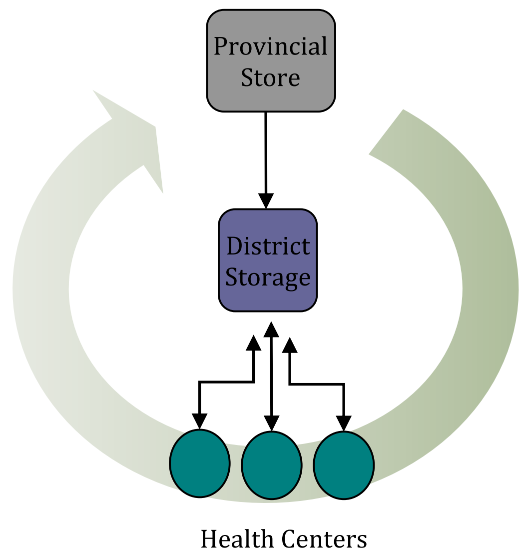


**Figure 2: Dedicated Logistics System**
*Dedicated personnel follow transport loops to deliver vaccines directly to health centers.*

***Processes***. The DLS introduced demand-driven elements by allowing dedicated, trained logistics personnel to make changes to the forecast-driven allocation plan based on up-to-date service delivery-level consumption data. Vaccines and supplies from the provincial level are delivered by field coordinators directly to the health facilities using transport loops in three delivery zones on a monthly basis. During these distribution runs, the field coordinators, one for each of the delivery zones, collect data, provide maintenance on the cold chain, deliver appropriate quantities of vaccines and supplies based on real-time consumption data, and provide supervision to health workers. Policies, procedures, and scopes of work were defined and approved by the DPS.

***Data***. The DLS takes advantage of the fact that the last mile of delivery is the first mile of data. Using paper-based forms and, in some cases, tablet computers, field coordinators collect data directly from the health facilities which is transferred into an enhanced online information system. They check the quality of the data, provide feedback to the health workers on program performance and ways to improve data quality, and facilitate the flow of data to the provincial level for monitoring and analysis of performance. This direct data collection component reduces the opportunity for human error seen during the typical data aggregation process up the administrative tiers. Nine key performance indicators are reviewed each month with the provincial EPI team to make ongoing changes to the



[4] Kane M. 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. Nov 2008.
[5] VillageReach. Comparison of costs incurred in dedicated and diffused vaccine logistics systems: Cost-effectiveness of vaccine logistics in Cabo Delgado and Niassa provinces, Mozambique. June 2009.

forecast allocations to accommodate changes in demand and other optimization improvements to the system.

***Equipment***. As distribution is initiated from the provincial level, cold chain storage and vehicles can also be concentrated at the provincial level instead of diffused through many levels. For example, the district level holds buffer stock for emergencies but no longer acts as a warehouse for health facilities, thus removing the requirement for additional cold chain capacity. (More can be read about cold chain maintenance here).[6] Similarly, vehicles, financial support for fuel, and required maintenance are also concentrated at the provincial level, reducing the need for a vehicle in each of the ten or more districts to only three in order to serve the three delivery zones.

***People***. Primary operational responsibility for inventory management and reporting, cold chain maintenance, and distribution tasks is shifted away from health facilities and district level personnel and consolidated to dedicated field coordinators stationed at the provincial level. Trained as logisticians, the field coordinators can focus on supply chain management which frees up health workers' time to focus on patient care. (More analysis of these benefits is documented here).[7]

While logistics tasks are consolidated and professionalized, the DLS does not exclude district EPI managers and health center workers from the vaccine supply chain process. VillageReach supports the district level EPI managers to accompany the distribution to provide supportive supervision to health workers, maintaining the lines of responsibility for district-level supervision while efficiently using the skills of a logistician. In effect, the DLS creates a regular network between the various levels of the health system on which more than just vaccines and supply chain data can flow.

*"Before the DLS, visits to the health centers were every few months or when we could take advantage of an NGO partner visiting the health center. But now, we go every month. Monthly visits help me a lot as the district EPI manager, because we don't just drop off vaccines but can also check the refrigerator and monitor data on performance, things that we would only hear about second hand previously. Now we see things directly at the health center and provide real-time support."*

Cândida Persina Chaves, EPI manager,
Bilene District
Gaza Province, Mozambique

***Funding***. One of the key challenges to any distribution system is having funds available for operational expenses when and where needed; this is particularly challenging in low-resource settings where many health programs must negotiate for these scarce resources. This challenge is additionally strained at the district level which is dependent on higher administrative tiers to allocate resources. Introducing the DLS consolidates distribution



[6] VillageReach. Keeping the cold chain cold: reaching the final 20 policy paper series. 2014. http://villagereach.org/vrsite/wp-content/uploads/2009/08/Village-Reach_Keeping-the-Cold-Chain-Cold.pdf
[7] VillageReach. Other duties as required: efficient use of human resources: reaching the final 20 policy paper series. 2014. http://villagereach.org/vrsite/wp-content/uploads/2009/08/VillageReach_Other-Duties-as-Required.pdf

responsibilities, and thus key expenses, at the provincial level, where government resources are more likely to be available. Using a cost-share approach, both the DPS and VillageReach contribute to the operational costs of distribution. At the province level, fuel is purchased, per diems are paid for, and vehicles have more opportunities to be maintained. With this system design, distribution costs are transparent and easily analyzed. The drawback to knowing the true costs of a distribution system, however, is it appears to be more expensive, particularly when compared to an ad-hoc, multi-tiered system which masks true costs borne by health workers filling in the distribution gaps. Ensuring vaccine availability at health centers costs money. Expenses that have historically been out of sight should be included in budgets based on true costs, and funds must be available at the distribution point.

***Political will***. It is stating the obvious to say that any system redesign takes leaders who are willing to question status quo practices and are committed to using innovation to improve the performance of their vaccine supply chains.[8] The DPS decision makers in these four provinces in Mozambique demonstrated this leadership capacity and willingness to test innovations to improve the vaccine supply chain. The medical chiefs and EPI managers have seen the positive results of the DLS and are now active proponents of the system, becoming advocates for national-level decision makers.

*"It was not easy to convince policy makers in Gaza to change from a system that had been followed for more than 30 years to a new and innovative approach. I admit that initially there was some resistance, but, with time, good sense prevailed and with it came a readiness for higher quality of care to the community, particularly in rural areas at the last mile of service delivery."*

Bertur Alface
Medical Chief, Gaza Province, Mozambique

*Read Bertur's complete blog post on the DLS here.*

The DLS has gone through transition as it is moving towards sustainability. What started as a project with 100% financial and management support from an outside NGO has transitioned to a cost-share approach with government personnel and management, and with only minimal financial and technical support from VillageReach.

As with any system design, the DLS is not without its challenges, and a poor performing aspect of any of these components can put the entire system at risk. In Mozambique, government funding reliability is an on-going struggle in one province, but strong leadership in another province has neutralized the funding flow challenge by ensuring it is included in the government budget. Other critics argue the DLS is contradictory to the decentralized government; however, with the consolidation of distribution transport and resulting regular, monthly distribution, the district EPI managers now travel with the field coordinators every

[8] Haddad S, Bicaba A, Feletto M, et al. System-level determinants of immunization coverage disparities among health districts in Burkina Faso: a multiple case study. BMC Int Health Hum Rights; 2009, 9 (Suppl 1).

month to supervise each of their health centers. The important concept is that the components of the system design have to fit together, finding that "sweet spot" of efficiency which is dependent on the particular context.

## Global Innovations at the Last Mile

Different innovations are being tested to improve the performance of supply chains in both public and private sectors.

### Multiplicity in Supply Chains

Some public health supply chain systems have drawn from the private commercial sector and are moving toward multiplicity in supply systems, different than the recent trend of integration of supply chains. Bornbusch and Bates discuss this from a private commercial sector perspective as a risk management approach.[9] In Uganda, a new supply chain was created for family planning commodities to serve the private sector which has grown to serve both private and the NGO sector. Bangladesh introduced a parallel supply chain for family planning commodities alongside the central medical stores; this separate system ensured a reliable supply of family planning products in the public sector, leading to an increase in demand for these products. Both advantages and disadvantages exist with multiplicity. On the beneficial side, the system has more flexibility; it can lower costs through competition; and segments can be tailored to program-specific needs. On the other hand, multiplicity creates a need for increased oversight, management and coordination across the entire supply chain; it can increase cost and potential inefficiencies; and could have the unintended consequences of reducing flexibility through over-specialization. The key to multiplicity is finding the appropriate combination of system components that results in system optimization.



### Modeling for System Design Optimization

Originally used in the private commercial sector, modeling uses computer simulation to determine how the different components of a system, such as demand, distribution networks, transportation routing, or storage capacity, can be arranged to produce optimized results. Several models are available (Unified Health Model, the 2020 Supply Chain Model, HERMES, and the vaccine logistics model at PATH-WHO).[10] The HERMES model has been used in both Niger and Benin to evaluate structural redesign options, cold chain capacity, and transport loops in order to find the optimal system for the vaccine supply chain.[11,12] It is currently being applied in Mozambique to fine-tune the DLS. The Llamasoft supply chain design software has been used in the commercial sector and is now being applied to public health supply chains, as in the on-going work in Mozambique with the central medical stores. While modeling takes into account the different components of the supply chain, political will and leadership is a key component that can't fit neatly into a computer simulation and must be taken into account for any modeling activity to be introduced and the results acted upon for system optimization.

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[9] Bornbusch A, Bates J. Multiplicity in public health supply systems: a learning agenda. Glob Health Sci Pract J. 2013; 1.
[10] Project Optimize Newsletter. Modeling tools under development. 2010; 5. http://www.who.int/immunization/programmes_systems/supply_chain/optimize/Optimize-newsletter-June-2010.pdf.
[11] Haidari L, Connor D, Wateska A, et al. Augmenting transport versus increasing cold storage to improve vaccine supply chains. PLoS ONE. 2013; 8(5).
[12] Brown S, Schreiber B, Cakouros B, et al. The benefits of redesigning Benin's vaccine supply chain. Vaccine. 2014; 32.

## GAVI Alliance Supply Chain Strategy

The GAVI Alliance Board has recently approved an immunization supply chain strategy, which was developed to respond to the realization that the current in-country supply chains are not meeting WHO standards and the risk will only increase due to higher vaccine volumes, doses and cost. While considering most components of the supply chain, a central component of the GAVI strategy is system design and optimization. Within this component, the strategy calls for the development of guidance, advocacy and an evidence base for system design; the use of modeling to facilitate innovation in forecasting and network integration; building system design capabilities regionally and locally; and finally, the development of tools to support country-level system design planning and implementation. This strategy provides much needed global leadership and guidance for countries that are committed to improving their vaccine supply chains.

# Conclusion

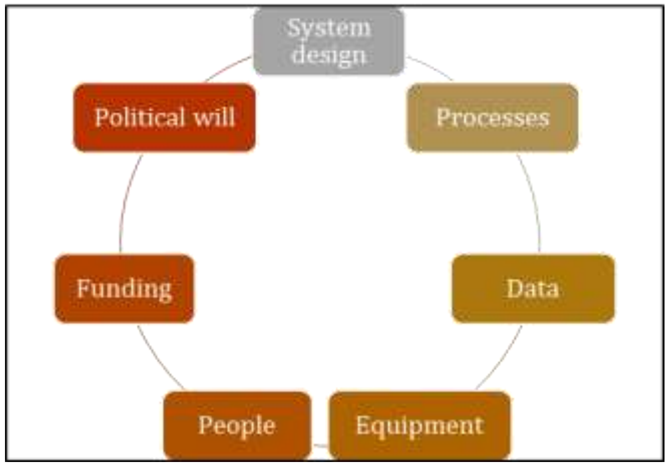
It is an exciting time for immunization programs as new vaccines are being introduced and new technologies become available, thus increasing the possibilities of reaching every child with life-saving vaccines. The same intensity and level of attention and focus given to new technologies, however, must also be applied to vaccine supply chain design and distribution systems.[13] Without considering system design, new vaccines will end up in a stock-pile with no efficient way for distribution. System design can be a challenging concept to introduce as it requires an open-mind evaluation of current operating practices that are known and comfortable and instead considering doing something new that may be unknown or not clearly understood. Any change to the existing system will affect the status quo to the benefit of some and the detriment of others.



It is evident from countries such as Mozambique and Benin where system design has been introduced that the results of the changes have had a positive impact in the performance of the vaccine supply chain. The fundamental concept is finding the "sweet spot" of system design, where all the components of the supply chain complement each other to be most efficient in that particular context. No design is perfect for all situations but has to be adapted appropriately and flexible enough to continue to respond to changes in the future. It's a question of how long can an existing system design be repaired before it's time to consider a new system design.

[13] Sabot O, Yadav P, Zaffran M. Maximizing every dose and dollar: the imperative of efficiency in vaccine delivery. National Bureau of Asian Research. 2011.

## Policy Series Background




*Components of the Vaccine Supply Chain*

This paper is the third in a series addressing the components of the vaccine supply chain. The health supply chain is a dynamic ecosystem which can increase access to high quality products by efficiently bringing the different components together to ensure delivery of commodities, as seen in the figure above. *System design* involves the set-up of the components of the supply chain system and how they interface with each other. The *processes* and policies determine how logistics practices get implemented in the field. Information and *data* flow influence forecasting, procurement, and daily management of the system, both at the global and in-country levels. *Equipment* ensures vaccines are delivered and have proper storage at every point of the supply chain. A key component is the *people* who operate and influence the supply chain and their capabilities, expertise, culture and behavior. The availability of *funding,* and particularly the flow of funding for each of the different levels of the system, is vital to ensuring delivery of vaccines. Finally, *political will* and the aspirations of leaders and champions can influence the performance of a supply chain by regulation and creating an enabling environment. Determining how the seven main components of the vaccine supply chain work together ultimately influences the degree of availability of vaccines at the point of immunization.

Future papers in this series will address other components, drawing on the evidence from the last mile of vaccine distribution through the *Final 20 Project* and global experience.

**For more information, please visit** www.villagereach.org.

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