System redesign of the immunization supply chain: Experiences from Benin and Mozambique

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ABSTRACT

Introduction: Evidence suggests that immunization supply chains are becoming outdated and unable to deliver needed vaccines due to growing populations and new vaccine introductions. Redesigning a supply chain could result in meeting current demands.

Methods: The Ministries of Health in Benin in Mozambique recognized known barriers to the immunization supply chain and undertook a system redesign to address those barriers. Changes were made to introduce an informed push system while consolidating storage points, introducing transport loops, and increasing human resource capacity for distribution. Evaluations were completed in each country.

Results: Evaluation in each country indicated improved performance of the supply chain. The Effective Vaccine Management (EVM) assessment in Benin documented notable improvements in the distribution criteria of the tool, increasing from 40% to 100% at the district level. In Mozambique, results showed reduced stockouts at health facility level from 79% at baseline to less than 1% at endline. Coverage rates of DTP3 also increased from 68.9% to 92.8%.

Discussion: Benin and Mozambique are undertaking system redesign in order to respond to constraints identified in the vaccine supply chain. Results and learnings show improvements in supply chain performance and make a strong case for system redesign. These countries demonstrate the feasibility of system redesign for other countries considering how to address outdated supply chains.

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1. Background

Evidence suggests that immunization supply chains (iSC) are becoming outdated and unable to deliver needed vaccines due to growing populations and new vaccine introductions. According to the Gavi Vaccine Alliance analysis of recent Effective Vaccine Management (EVM) assessments in 57 countries, the majority do not meet the WHO recommended 80% score across most of the nine categories of supply chain management, with results particularly low for the categories of stock management, maintenance, and distribution [1]. Studies also show that the standard four-tier design of the iSC could be simplified and tailored to the country context to reduce operating costs and reduce redundancies of storage locations and transport routes [2]. Interest in improved iSC is gaining traction globally as thought leaders have called for vaccine supply systems to be strengthened and optimized in order to be more efficient and effective to respond to current growing populations and vaccine demand [3]. A system redesign can alter the structure of the supply chain through reducing distribution tiers, shifting warehouse locations, or changing transport routes to create a dynamic, efficient, data-driven supply chain [4].

The Ministries of Health (MoH) in Benin and Mozambique have undertaken system redesign activities to address the underperforming iSC. In Benin in 2011, the MoH was faced with a strained iSC with insufficient cold chain capacity due to the introduction of pneumococcal conjugate vaccine (PCV) and the impending introduction of Rotavirus vaccine [5,6]. In Mozambique in 2002, according to administrative data, the northern province of Cabo

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Delgado had a vaccine coverage rate lower than the national average and was reportedly experiencing challenges in the iSC including frequent health facility vaccine stockouts, unreliable transportation, uncoordinated vaccine supply requirements, and lack of data.

The distribution systems in both countries were originally designed with four tiers (Table 1). In Benin, the national level uses cold trucks to deliver to some department stores with the remaining department stores using $4 \times 4$ trucks to fetch vaccines from the national level. The sub-district level stores use $4 \times 4$ trucks to fetch from the department level, and the health facilities use motorbikes to fetch from sub-districts. In Mozambique, the national level uses air cargo to deliver the vaccines to the six central and northern provinces while the three southern provinces use $4 \times 4$ trucks to fetch the vaccines from the national warehouse. Provinces are responsible for delivering to the district level using $4 \times 4$ trucks; the district level is responsible for ensuring vaccine availability at health facilities, either through delivery with $4 \times 4$ or health workers fetching the vaccines using public transport.

This paper documents the system redesign process from introduction of demonstration projects through evaluation and compares results between these two countries to estimate the feasibility for replication in other countries.

### 2. Benin

#### 2.1. Benin: methods

The MoH’s National Agency for Vaccination and Primary Healthcare (ANV-SSP) engaged a technical team, including Agence de Médecine Préventive (AMP), the HERMES Logistics Modeling Team, PATH, and Transaid, for system redesign. A baseline assessment of iSC performance was conducted using the EVM assessment, updated national cold chain equipment inventory, a cost analysis including EPI staff time related to logistics, and assessment of the MoH transport management capacity. During a July 2012 workshop, national and global partners used the baseline assessment to identify three alternative supply chain designs to model [7].

The HERMES (Highly Extensible Resource for Modeling Supply Chains) simulation modeling tool was used to explore the impact of the three alternative designs on product availability and logistics cost per dose in the hypothesis of Rota vaccine introduction. The HERMES tool generates detailed discrete-event simulation models to compare efficiencies across system designs as described in previous publications [8–11]. Modeling results demonstrated that the most efficient system redesign for Benin involves consolidating sub-district vaccine stores to one district vaccine store and introducing truck loops. As previously reported, the modeling results predict that this design would increase vaccine availability from 71% to 99% and reduces the logistics cost per dose from $0.26$ USD to $0.19$ USD [5].

Following MoH approval and using the modeling results, a demonstration project started in November 2013, in Comé district in Mono-Couffo department with the approved supply chain design. The project installed highly performing cold chain equipment and introduced the informed push system with monthly direct delivery from district to the 37 health facilities using real-time data from those facilities for determining the required quantity of vaccines. To build a cadre of supply chain managers, a district level logistician was trained and tasked with collecting vaccines from the regional store; conducting monthly visits to each health facility for vaccine distribution, safety box collection and data collection; providing supportive supervision; and analyzing data for improved distribution planning. Eighty health facility vaccinators also received refresher training.

After a year of implementation, an external EVM assessment was conducted in 2014 by UNICEF in Comé and a control district to evaluate the impact of the system design changes to iSC performance.

#### 2.2. Benin: results

The results of the evaluation indicated improved EVM scores in comparison with the control district and with the baseline. The EVM performance score at the district level significantly improved between baseline and endline in Comé, particularly in the focus criteria of the pilot: the distribution score increased from 40% to 100%; vaccine management practices increased from 58% to 94%; and infrastructure increased from 55% to 94% with the procurement of improved cold chain equipment. Comé district also scored higher than the control district in all criteria areas, most notably in distribution (100% compared to 32%) and vaccine management practices (94% compared to 63%) (Table 2).

Improvements were also noted at the health facility level in seven out of eight criteria, and results exceeded the recommended

### Table 1

<table>
<thead>
<tr>
<th></th>
<th>Benin</th>
<th>Mozambique</th>
</tr>
</thead>
<tbody>
<tr>
<td>National depot</td>
<td>7 department stores and one regional store</td>
<td>National warehouse</td>
</tr>
<tr>
<td></td>
<td>80 sub-district level stores</td>
<td>128 district level stores</td>
</tr>
<tr>
<td></td>
<td>763 health facilities</td>
<td>1392 health facilities</td>
</tr>
<tr>
<td>Province level</td>
<td></td>
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<td></td>
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</tbody>
</table>

### Table 2

Consolidated performance score of EVM at district level, Benin.

<table>
<thead>
<tr>
<th>EVM criteria</th>
<th>2012: Baseline sub-district depot Comé district (%)</th>
<th>2014: Endline district depot Comé district (%)</th>
<th>2014: District depot control district (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature monitoring</td>
<td>74</td>
<td>81</td>
<td>67</td>
</tr>
<tr>
<td>Storage capacity</td>
<td>52</td>
<td>89</td>
<td>75</td>
</tr>
<tr>
<td>Infrastructure</td>
<td>55</td>
<td>94</td>
<td>94</td>
</tr>
<tr>
<td>Maintenance</td>
<td>64</td>
<td>79</td>
<td>6</td>
</tr>
<tr>
<td>Stock management</td>
<td>54</td>
<td>70</td>
<td>63</td>
</tr>
<tr>
<td>Distribution</td>
<td>40</td>
<td>100</td>
<td>32</td>
</tr>
<tr>
<td>Vaccine management practices</td>
<td>58</td>
<td>94</td>
<td>63</td>
</tr>
<tr>
<td>MIS &amp; supportive functions</td>
<td>73</td>
<td>71</td>
<td>53</td>
</tr>
</tbody>
</table>
80% for five criteria. In comparison, none of the criteria reached 80% in the baseline study. Score for all eight criteria were higher in Comé district than in the control district (Table 3) [12].

As reported in a related article specific to the Benin implementation in this journal [13], results of the economic study show district level cost per dose administered increased from US $0.09 before system redesign to US $0.16 after implementation, mainly due to high initial investment and operational cost of transport and cold chain equipment, yet still in-line with what the modeling predicted. Interviews with health workers in the anthropologic study suggested that the redesigned system was associated with improvements in motivation and professional awareness through training, supportive supervision, and improved work conditions.

### 3. Mozambique

#### 3.1. Mozambique: methods

The Provincial Directorate of Health (DPS) in Cabo Delgado province worked with a technical team of non-governmental organizations (NGO) partners VillageReach and the Community Development Foundation (FDC) to design a five-year pilot project with an informed push system to serve the 111 health facilities in Cabo Delgado. This new structure removed the district level as a distribution point, becoming a warehouse for emergency stock only. Distribution zones were introduced using transport loops for direct delivery from the provincial store directly to health facilities. Dedicated logisticians became responsible for distribution by zone, direct data collection from health facilities, and providing supportive supervision to health workers. New cold chain equipment was also installed where needed.

An evaluation of the pilot was completed in 2008 to evaluate vaccine coverage and iSC performance. Data from the 2003 Demographic and Health Survey (DHS) were used as baseline for vaccine coverage. A representative household survey used a cross-sectional, community-based survey that assessed immunization coverage rates using the WHO 30 × 7 immunization coverage cluster design with 237 households interviewed for the sample in the pilot project province. In the control province of Niassa, the sample used the modified WHO 20 × 10 immunization coverage cluster design to include 233 households in six districts that reflected the varied socio-economic conditions in the province. To estimate the impact of the project, the DHS 2003 dataset and the results of the coverage cluster survey 2008 were compared using SPSS version 16.0 and a logistic regression model. The DHS data was weighted using the sample weight in the dataset divided by 1,000,000. Cross-tabulations and Pearson chi-squared tests were used to compare the datasets.

Qualitative interviews were conducted with 27 key health workers in the same clusters as the coverage cluster survey. The structured, open-ended questionnaires focused on vaccine delivery, vaccine stock, cold chain equipment, and cost of vaccine-related activities. Interviews were conducted in private settings to ensure confidentiality.

Supply chain related cost-analysis used an Excel-based cost model for comparison between the pilot province and the control province, Niassa. The cost model included the portion of transport, personnel, cold chain, and vaccine and other EPI-related supply costs. Actual incurred costs from Cabo Delgado were entered into the model; in Niassa, a sampling of data was collected in field work conducted at nine health centers and eight districts that were selected randomly using probability proportional to size. The model projected and calculated the costs to operate the iSC for one year in both provinces, the total cost per child receiving DTP3 as a proxy for a fully immunized child, and total cost per vaccine dose delivered.

#### 3.2. Mozambique: results

Results of the evaluation show a change in DTP3 coverage rate in children 12–23 months old in the pilot province, increasing from 68.9% in 2003 to 92.8% in 2008 (OR 5.8, 95% CI 3.2–10.5), a 23.9 point difference. Drop-out rates between DTP1 and DTP3 decreased from 12% at baseline to 3.8% at endline. For comparison, the DTP3 coverage rate in the control province increased from 54.6% to 71.9% (OR 2.1, 95% CI 1.3–3.5), a 17.3 point difference. The national DTP3 coverage rate in 2003 was 70.9% (DHS Survey results), increasing to 72% in 2007 according to administrative data and surveys by WHO and UNICEF (Table 4).

Results also show stockouts reduced from 79% at baseline to less than 1%. Over 90% of staff interviewed at health facilities included in the evaluation reported being visited by the distribution team every month; 10% reported having to fetch vaccines from the district. Twenty-six of the 27 health facilities included in the evaluation had a working refrigerator over one year after the pilot ended. Because of the higher vaccine coverage rates in Cabo Delgado than in Niassa, the pilot project proved 17% more cost-effective, at $5.03 USD per child vaccinated with DTP3 versus $6.07 USD in the control province. The pilot project was 21% less expensive per dose delivered than the Niassa system at $1.18 USD per dose delivered compared to $1.50 USD in the control province.

Table 5 summarizes this process in each country.

#### 4. Discussion

In order to respond to constraints identified in the iSC, both Benin and Mozambique introduced changes to the iSC, resulting in documented improvements in performance of the iSC in both countries, as well as improved coverage rates in Mozambique. Notably, other countries in sub-Sahara Africa also achieved improvements in DTP3 coverage during the same time period, likely due to the establishment of Gavi and increased support for vaccines across this region. Additionally, both projects included
capital investments in transport and cold chain equipment and additional resources for training and supervision, which inevitably had an impact on the improved vaccine availability as well. Even with these influential factors, the evidence suggests that system redesign introduced an efficient and effective process for managing the new investments. The experiences in Benin and Mozambique, despite being different countries and contexts, present similar improved results and learnings that make a strong case for redesigning the iSC.

In each country, the system redesign process responded to the call from global thought leaders for iSC improvements as well as the notable constraints in the in-country performance of the iSC. The process engaged stakeholders who analyzed available data on existing iSC challenges and gaps and determined alternative system designs relevant to the current circumstances in each country.

Evidence from each evaluation suggests that system redesign can increase performance of the iSC. In each country, system redesign included changing storage locations, increasing supply chain management capacity through dedicated logisticians, and improving cold chain performance.

In Benin, modeling results identified an informed push design to be most efficient and feasible, which was confirmed by an evaluation of the demonstration project. Those results identified improvements in the distribution criteria of the EVM assessment, which reflect more reliable delivery mechanisms, better reporting systems, correct use of cold boxes during transportation, and a capacity for transport contingency planning. The improvements in vaccine management indicate better knowledge of vaccine quality control practices and wastage control.

In Mozambique, the informed push system resulted in reduced stockouts and a more reliable system of monthly deliveries, reducing the burden on health workers to fetch vaccines. The system relies on real-time data at the health facility level to determine vaccine quantities to deliver. This assumes more accurate quantification with reduced over- or under-stocking, although overstocking was not evaluated during this pilot. Results suggest that this system more efficiently improves vaccine availability at the health facility level than the typical multi-tiered system. Coverage rates also increased, yet not solely attributable to the pilot.

The cost-efficiencies found in the Mozambique project show that the informed push model can improve supply chain performance while reducing costs in the particular context of Cabo Delgado. In Benin, cost-savings were not seen in the immediate start-up of the demonstration project, due to the necessity to upgrade the underperforming and inadequate cold chain, but the modeling results show reduced cost per dose when compared to a multi-tiered system. These findings reflect the evidence that system redesign can bring cost-savings to vaccine programs through more efficient supply chains. Modeling proved to be a helpful tool to identify system design options in Benin; it has since been used in Mozambique to validate the system design in Cabo Delgado and identify options across all provinces.

It is notable that each country had a champion who was willing to question the status quo of the current system, advocate for necessary changes, and remain resilient when facing criticism. In Benin, the political will and champion were the driving force at the sub-national level. In the following five years, three additional provincial leaders adopted an informed push system to question the status quo of the current system, advocate for necessary changes, and remain resilient when facing criticism. In Benin, the political will and champion were the driving force at the sub-national level. In the following five years, three additional provincial leaders adopted an informed push system.

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It is notable that each country had a champion who was willing to question the status quo of the current system, advocate for necessary changes, and remain resilient when facing criticism. In Benin, the political will and champion were the driving force at the national level. In decentralized Mozambique, provincial level champions drove the subnational change and then became advocates for a wider system design approach at the national level.

Since results of the pilot in Benin, the MoH has decided to scale-up an optimized iSC to all districts through a four-year action plan developed by partners and endorsed by the Interagency Coordination Committee (ICC). A national logistics technical working group has been established to oversee the scaling up, and a baseline study was conducted in ten districts in 2015. A study is ongoing in Comé district to assess the feasibility to integrate reproductive health products in the redesigned immunization supply chain, in order to increase reproductive health supply chain performance and pool resources to contribute to financial sustainability of the system.

In Mozambique, the system redesign approach began as a five-year project in one province with provincial leadership driving the change at the sub-national level. In the following five years, three additional provincial leaders adopted an informed push system.
and adapted the design to the specific provincial context, such as including district level personnel on distribution activities for supervision and support, or using two-month delivery frequencies where appropriate. This phase shifted to government management with government personnel responsible for distribution, data collection and supervision, and operating costs shared by the partnering NGO. The country is currently using HERMES modeling for national level system design to find efficiencies across all provinces.

It will be important to continually monitor and evaluate scale-up efforts in these two countries, particularly as more countries and global thought leaders are seeking more efficient and effective iSC. These findings can be applied by other countries interested in system redesign, such as Zambia and the Democratic Republic of Congo, both of which have underperforming iSC, have champions who recognize the possibilities of improvements and finding efficiencies, and are currently advocating for system redesign and preparing for a modeling activity.

5. Limitations

In Mozambique, the pilot and comparison provinces are different sizes, populations, and have different health system characteristics. Additionally, cost data was difficult to gather in the control province, which possibly can lead to reduced confidence in the survey results. In Benin, the demonstration project was implemented in only one district so would need to be adapted to the specific context in other districts. Additionally, it is difficult to compare the results between the two countries as provincial-level EVM results are not available in Mozambique. Each project was implemented in specific locations in Benin and Mozambique; results suggest these changes can introduce benefits to the performance of the iSC but cannot guarantee similar results in other locations.

6. Conclusion

The results of the system redesign in specific provinces in Benin and Mozambique show improvements in supply chain performance influenced by changes to the design of the supply chain. This approach engaged stakeholders, used evidence for decision making for introducing a new supply chain design that is appropriate to the specific context, and resulted in a better performing supply chain. These examples demonstrate the feasibility of system redesign while highlighting key learnings for other countries considering a system redesign effort to respond to the need for optimized and strengthened vaccine supply chains.

Conflict of interest

The authors have no conflict of interests to declare.

References