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Original Article

Cost Analysis of Current Distribution and Redesigned Distribution Systems for Vaccines in Rwanda

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Abstract

Background
Immunization supply chain management is among the components of immunization program, making vaccines delivery possible to reach every child. Nevertheless, it has been found to be static with rapid changes linked to the introduction of new vaccines. The success of Rwanda immunization program with coverage of 94.3% was attributed to human resource and capital investment from both the Ministry of Health and its development partners. However, the current distribution system design does not contribute to self-financing of the program in the long-run considering the distribution mode and frequency applied. The cost analysis study has never been done before and is expected to address the issue of long-term sustainability of the program as it will inform the system re-design activities.

Objective
Assessing how much the program would save if the system is re-designed by changing distribution mode and frequency from the Central Vaccine Store to District Vaccine Stores.

Methods
Administrative and financial records were reviewed to determine the cost of the current vaccine distribution system to be compared to estimated cost of a proposed distribution system with reduced frequencies between Central Vaccine Store and District Vaccine Stores.

Results
By comparing the costs of the two systems, applying the proposed distribution model with less distribution frequencies reduced the current cost by 37%.

Conclusion
The findings confirm a huge opportunity of getting the current vaccine distribution costs reduced when the distribution system is redesigned, hence contributing to financial sustainability of the vaccination program.

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Keywords: Cost analysis, distribution system design, vaccines

Background

Immunization program is one of the recognized and successful cost-effective public health investments.[1] Studies conducted in USA (Influenza vaccination. Health impact and cost effectiveness among adults aged 50 to 60 and 65 and older) and Canada (Analysis finds Ontario's universal flu vaccination policy cost-effective) showed that estimated cost effectiveness of vaccination in those aged over 65 years was USD 980 per Quality Adjusted Life Years (QALY) saved in 2000.[2] In Canada, a strategy of universal coverage reduced influenza cases by 61% and related death by 28%.[3] With proven strategies making it accessible to all, even in hard to reach areas, the immunization program is quite an attractive intervention in health to invest in.[4]

The immunization supply chain management is a critical area that should operate with success to satisfy customers' need. It involves different components that require critical devotion to make it successful and those include: human resource, systems and all operations involved from vaccine production point to the beneficiaries. The introduction of new vaccines comes as solution to save lives in low & middle income countries, although the supply chain system at this point has become constrained for various reasons where the distribution system may be impinged among others.[5]

The immunization supply chain management drives immunization program by making delivery of vaccines to every child possible.[6] Rwanda immunization program was created in 1978 with six antigens to combat six vaccine preventable diseases, and with only one component of supply system, the program became operational in 1980. The program was operating effectively until 1994 during the genocide against the Tutsi when all activities related to vaccination ceased from April to August 1994.[7] The immunization supply chain management has been very effective with increase of immunization coverage that led to the reduction of child mortality rate.[8] However, the supply chain gradually became outdated with years as many changes are being made with new technologies.[9] The changes made include the introduction of new vaccines in the last two decades that affected vaccination logistics and distribution system.[10]

Using WHO effective vaccine management (EVM) tool, an assessment was performed to evaluate country's performance with regard to the immunization supply chain management. Distribution was one of the nine criteria of effective vaccine management, and in 2015, it recorded low performance (17%). Although it has improved to meet the target during the 2018 assessment, it is obvious that an improvement is required for efficiency. This is also linked to other components like vaccine management and information system also found to be under the target score of 80%.[11]

Since 2000, which is the decade new vaccines were introduced, the supply chain has been encountering difficulties related especially to the human resource capacity, with issues such as insufficient and lack of adequate skills despite some achievements related to new vaccines introduction and increased coverage rate.[12]

Immunization supply chain system in Rwanda is made of a three-level system; Central Vaccine Store (CVS), District Vaccine Stores (DVS) and Health Centres. Using a pull system (where DVS are responsible for ordering and collecting vaccines from CVS) with a month of stock level, DVS personnel would come to collect vaccines at any moment; this would depend on their convenient time.

There was no plan of distribution until 2014 and only two personnel were working as logisticians and could also go to the field for other supply chain activities including Cold Chain Equipment (CCE) repairs. Thus, those from DVS would come at CVS to collect vaccines and go back without any. Proper planning and insufficient means of communication were the most challenging issues. Later, the program decided to redesign the system and elaborated a plan of distribution, which was done in a period of two weeks per month before 2015. This plan was also revised in 2016 and became a one-week distribution frequency per month. These two events of redesigning the distribution system were performed without any study on costs analysis for the program to evaluate its impact on the financial sustainability in the long-term.

WHO recommends EVM assessment every three years. In Rwanda, the Effective Vaccine Management (EVM) assessment has been conducted three times consecutively in nine years and areas of improvement were highlighted including vaccine arrivals and management information system.[13] The evidence that supplies are being delivered promptly is real as shown by the increased and maintained vaccination coverage.[14]

The quality is also required and optimization of supply chain management should be thought about as studies showed the gap in human resource in Middle Income Countries(MICs),[5] which was a case in Rwanda. Considering available opportunities, there is always a room for improvement to optimize the supply system. The Global Alliance for Vaccines Immunizations (GAVI) is supporting Rwanda immunization program up to 84%. This includes vaccines introduction co-financing, cold chain equipment and operational cost.[15] GAVI co-financing policy indicates in its objectives that, their purpose is to increase countries' budget for GAVI supported vaccines and immunization activities to sustain themselves and ensure vaccines are accessible to all. Countries are required to increase their contributions of co-financing level as they transition from low-income countries level to the middle-income countries level until they fully sustain themselves.[16]

Once the country graduates from GAVI support, it is better to have an alternative plan to avoid the catastrophic situation which may take lives of many. Rwanda plans to sustain the program, although it is not easy considering the scarcity of resources. Nevertheless, different approaches are being considered to find strategies that are cost-effective to ensure sustainability.

The Rwanda immunization program considered redesigning the Vaccine distribution system model as one of the ways to reduce the overall cost of the program by improving its sustainability. However, for the system to be redesigned, the program had to plan for expanding storage capacity using available opportunities including GAVI support through cold chain equipment optimization platform (CCEOP). This grant was meant to replace the outdated cold chain equipment in the system and increase storage capacity at all levels. Being eligible country for the support,[17] Rwanda applied for this grant which was approved in 2018.[18] With increased storage capacity at all level, health facilities will be able to store more quantities of vaccines which is expected to reduce distribution frequency. The distribution frequency will change from monthly to quarterly frequency. This change entails that distribution will occur four times per year instead of current twelve times per year that arise from the existing monthly distribution plan. Furthermore, push system will be applied whereby CVS will be delivering vaccines to the DVS using available refrigerated vehicles. By reducing vaccine distribution frequency, the program will not only reduce distribution cost but will also save time for the staff to monitor vaccination activities.[19]

Redesigning the distribution system is expected to be a sustainable solution given the anticipated reduction in cost of vaccines distribution, which is hugely dependent on external partners' support (mainly GAVI). This support is not expected to last for long, and it will come to an end at some point in the future.[20] There is no study related to the cost analysis of vaccine distribution system in Rwanda, this study will therefore show how much the program would save once the system is redesigned and contribute to the sustainability of the program.

Methods

Study design

The researcher used descriptive method to show how the vaccines distribution system is currently operating and how it can be redesigned to ensure its sustainability in the near future. Data on vaccines transportation costs (fuel costs, mission allowances for staff from DHs collecting vaccines, mission allowances for CVS staff distributing vaccines under proposed redesigned system, vehicles maintenance costs estimates) was collected and analyzed to establish the linkage between the distribution costs and sustainability of the program. The results from the study will inform policy makers and Immunization Program on what could be done to reduce the distribution costs.

Study population and sampling

The study presents the financial cost of the two vaccine supply systems from CVS to DVS. All stores were exhaustively included in the cost analysis. Therefore, sampling strategies were not required for this particular study.

Data collection tools

The tool used to collect data was an excel sheet designed for the purpose of this study only. The tool contained two key components:data related to the existing distribution system and that of redesigned distribution model.

Measurements

Administrative and financial records related to vaccine distribution were reviewed to determine the cost of current vaccine distribution and cost estimates for the distribution of the planned system re-design. We collected resource-use data for the vaccine, distribution system, including per diems and fuel for vehicles used in delivering or collecting vaccines and dry supplies between any of the two tiers of the immunization supply chain system.

Calculations for per diems were based on the ministerial law/order related to the travel allowances for the workers on mission;[21]this helped the researcher to determine how much each category of staff involved in vaccine distribution should be paid depending on the number of days spent on one mission. The second item costed is vehicle maintenance fees and this was calculated based on the available maintenance plan per year for the two recently acquired tracks. The third is fuel cost which was calculated based on the District Hospital (DH) locations determined by distance between those DHs and CVS, cost of current fuel per litter multiplied by distance in km considering vehicle consumption equaling 7km/l and an annual inflation rate was considered while projecting the cost of the two distribution systems in a period of 5 years.

For transportation of dry supplies, we considered outsourcing of the tracks, which could be done twice a year to reduce frequencies as DHs can store dry goods for six months, to complement the transportation of the cold storage by refrigerated tracks.

Data collection procedure

The researcher mapped the data information needed for the description of the vaccine distribution system in place and developed an excel data collection tool to properly capture, records and analyze data.

The data were collected from Rwanda Biomedical Centre, in Single Project Implementation Unit (SPIU) where financial records related to partner's funding programs are archived.

Data analysis

Data was collected and entered in a developed excel tool designed purposely for the data analysis of this study. Calculations were done based on costs of the existing vaccine and the proposed distribution systems. The proposed system consists of modified distribution model and distribution frequency. These calculations focused on (i) Costing of the existing distribution system, (ii) estimation of the proposed distribution system re-design, (iii) estimation of the cost saving for the immunization program once the proposed distribution model is implemented.

Ethical consideration

The study protocol and tool were approved by the University of Rwanda, College of Medicine and Health Sciences Institutional Review Board (Ref: 384/UR/CMHS/IRB/2019). A research protocol was developed and presented to the research workshop at University of Rwanda/ College of Medicine/School of Public Health, inputs and comments provided were considered for the final research protocol submitted to the Institutional Review Board for approval. The approval notice was granted and submitted to Rwanda Biomedical Centre/ Immunization program so as to be allowed to access the data.

Results

The cost of current vaccine distribution system in Rwanda.

The current distribution of vaccines is done using pull system where Health Centers (HCs) collect vaccines from DVS which is supplied with vaccines from CVS. This study shows the cost of vaccine supply from CVS to DVS per delivery. Table 1 below describes costed items for vaccine distribution per year. The projection of five years was also determined to know what a program would spend if the system was not re-designed.

Table 1. Five-year projected cost of the current distribution of vaccine at 5.5% inflation rate

	Costed items#	Cost* per month	Cost per yr (Baseline 2019)	Cost of yr 1- (2020)	Cost of yr 2 (2021)	Cost of Yr 3- (2022)	Cost of Yr 4 (2023)	Cost of Yr 5 (2024)	% cost increase in yr5
1	Fuel for DHs vehicles	3.071	36.852	38.879	41.017	43.273	45.653	48.164	**30.70**
2	Mission allowances for EPI Focal person	0.454	5.448	5.747	6.063	6.397	6.749	7.120	
3	Mission allowances for DH drivers	0.301	3.617	3.816	4.026	4.247	4.481	4.727	
Total cost		**3.826**	**45.917**	**48.442**	**51.107**	**53.918**	**56.883**	**60.012**	

#All DH combined; *Millions of Rwandan francs

Source: Data generated from the tool designed to describe the current vaccines distribution costs

This study revealed in Table 1 that the cost of vaccines delivery will keep rising at an annual inflation rate of 5.5% against the baseline cost of 2019 cost per delivery.

Every year, the program has to secure more than 45,917,400 FRW for vaccines delivery only considering 2019 as baseline. With five years' projection, the current cost will increase up to 30.7% by 2024. The annual budget support indicated above is externally funded (GAVI Support) and an increase on annual basis would affect the financial sustainability of the vaccines supply system.

There are shown three items costed in Table 1, namely a) fuel, b) mission allowance for the Expended Program for Immunization (EPI) supervisor and c) mission allowance for the driver. This study revealed that the vaccines reach the DVS at a cost of 3,826,450 FRW which make 45,917,400FRW per year considering a monthly distribution.

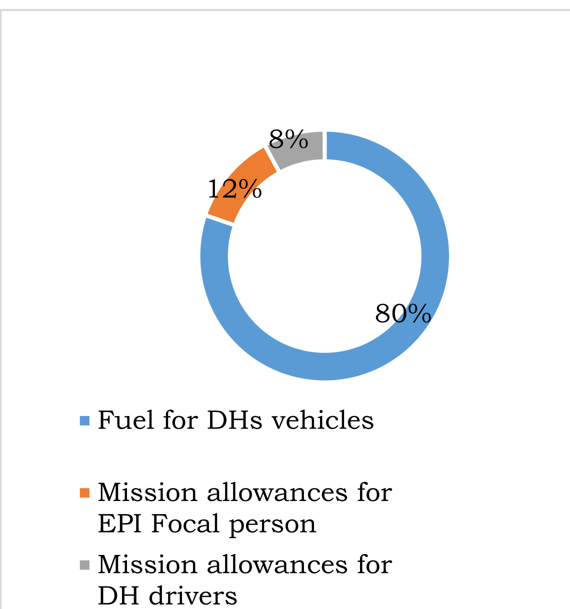

Figure 1. Vaccine distribution cost per year (all DHs combined)

Figure 1 shows the total cost of vaccine distribution for each item that requires funding. Of the three above mentioned items as indicated on this figure, the fuel takes 80% of the total cost, while mission allowances for EPI focal person takes 12% and the DH driver 8%.

Determine what the distribution system would cost if redesigned

The new design is about changing model from pull to push system where CVS will be pushing to DVS and HCs pull from DVS.

To be able to define the number of distribution frequencies that could happen once the system changed from pull to push system between primary (CVS) and secondary (DVS) levels, it is necessary to assess the suitable route planning (routing optimization) to ensure an uninterrupted supply and maximum cost savings per round of trip, the researcher proposed what was considered to be more efficient route plan. Table 2 shows the route planning and the cost of vaccine delivery per route per year.

Table 2. Estimated cost of the re-designed distribution system

DHs/Group	Distr. Cost/qtr	Fuel cost / delivery/DH/yr	Transport cost of devices/ DH (lorry 2.5-5t)/qtr	Transport cost of devices DH (lorry 2.5-5t)/yr	Mission allowance/ qtr	Mission allowance/ year
Bushenge Gihundwe Kibogora Mibilizi	87171	348,685.71	132,600	530,400	75,400	301,600
Kibuye Kabgayi Mugonero Murunda Kilinda	62177	248,708.57	132,600	530,400	75,400	301,600
Gisenyi Nemba Ruhengeri	49371.4	197,485.71	132,600	530,400	77,400	309,600
Kabaya Muhororo Shyira	43508.6	174,034.29	132,600	530,400	77,400	309,600
Nyanza Kabutare Kigeme Kaduha Munini	51593	206,372.57	132,600	530,400	75,400	301,600
Gakoma Gitwe Ruhango Kibilizi	62949	251,794.29	132,600	530,400	66,400	265,600
Nyagatare Gahini Kiziguro Ngarama	60048	240,192	132,600	530,400	70,400	281,600
Rwamagana Rwinkwavu Kibungo Kirehe	44280	177,120.00	132,600	530,400	70,400	281,600
Kibagabaga	17789	71,156.57	132,600	530,400	10,800	

Muhima Masaka Nyamata						43,200
Byumba Rutongo	20983	83,931.43	132,600	530,400	10,800	43,200
Ruli Rukoma	23760	95,040.00	132,600	530,400	10,800	43,200
Butaro Kinihira	34406	137,622.86	132,600	530,400	10,800	43,200
		2,232,144		6,364,800	631,400	2,525,600
		122,767.92		350,064.00		138,908.00
		2,354,911.92		6,714,864.00		2,664,508.00
Total estimated cost for vaccines delivery under re-designed system						**11,734,283**

Source: Data generated from the tool designed to estimate distribution cost of vaccines per year.

The grouping of DHs was done based on geographic information/data with which data were used to estimate how much the new distribution model (new frequencies) will be costing compared to the current model.

Table 3 indicates the total cost for key drivers (Fuel and Mission Allowances) per year.

Table 3. Total cost of vaccine delivery per year when route optimization is applied

DHS	Delivery cost for vaccines/Months		Delivery cost for the devices/year	Mission allowance/year
All DH	Fuel cost	2,232,144	6,364,800	2,525,600
	Inflation rate: 5.5%	122,767.92	350,064.0	138,908.0
	Total delivery cost & inflation rate	2,354,911.92	6,714,864.0	2,664,508.0
Redesigned system total cost/year				**11,734,283.92**

Source: Data generated from the tool designed to estimate the delivery costs per year in summary

The total estimated cost for vaccines distribution in Rwanda using the proposed frequency of distribution or delivery schedule is low compared to the current distribution costs. With an inflation rate of 5.5% FRW the total would be 11,734,283.92 compared to FRW 45,917,400. The inflation rate was added in case the plan was to initiate the new design in the following year. The program would make a net saving of 74.4% of the current distribution costs for the first year. The net saving is the ratio of the two estimated costs (current vaccine delivery and the re-designed vaccine delivery system), as per calculations below;

$$\frac{(45{,}917{,}400-11{,}734{,}283)}{45{,}917{,}400}*100=74.4\%$$

The cost of preventive and regular maintenance of the trucks was estimated in order to see how much this component cost is likely to affect the vaccines availability and projected costs saving, the details of preventive and regular maintenance are presented in Table 4.

Table 4. Estimated maintenance cost for the two tracks in Rwandan francs per year

No.	Item/	cost/ truck/qtr	Frequency/ yr		Costs for two trucks/yr
1	Vehicle Service Maintenance every 5,000 Km (one round trip/qtr)	536,683	4	2	4,293,463
2	Non-Maintenance Repairs as needed	1,238,825	1	2	2,477,651
3	Annual Maintenance of the track	5,200,000	1	2	10,400,000
	Total (estimated) cost for maintenance				**17,171,114**

Source: Data generated from the tool designed to describe the annual maintenance cost

Table 4 shows the total cost (17,171,114 Rwf) of maintenance for the two refrigerated trucks that will be added to the total cost of the vaccine distribution per year. This increases the total cost of the new distribution model to 28,905,398 Rwf for the first year making 37% decrease of the distribution cost compared to the current distribution system. The calculations below show details of the cost saving estimations.

$$\frac{(11734283+17171114)}{45917400}*100=62.9\sim 63$$

This shows that the re-designed distribution system will be using 63% of the initial cost where 37% of the initial cost is considered as total saving.

Figure 2 indicates the trends in vaccines distribution over five years when comparing the two distribution systems.

Results of this study revealed that current distribution system is more expensive compared to the proposed distribution design

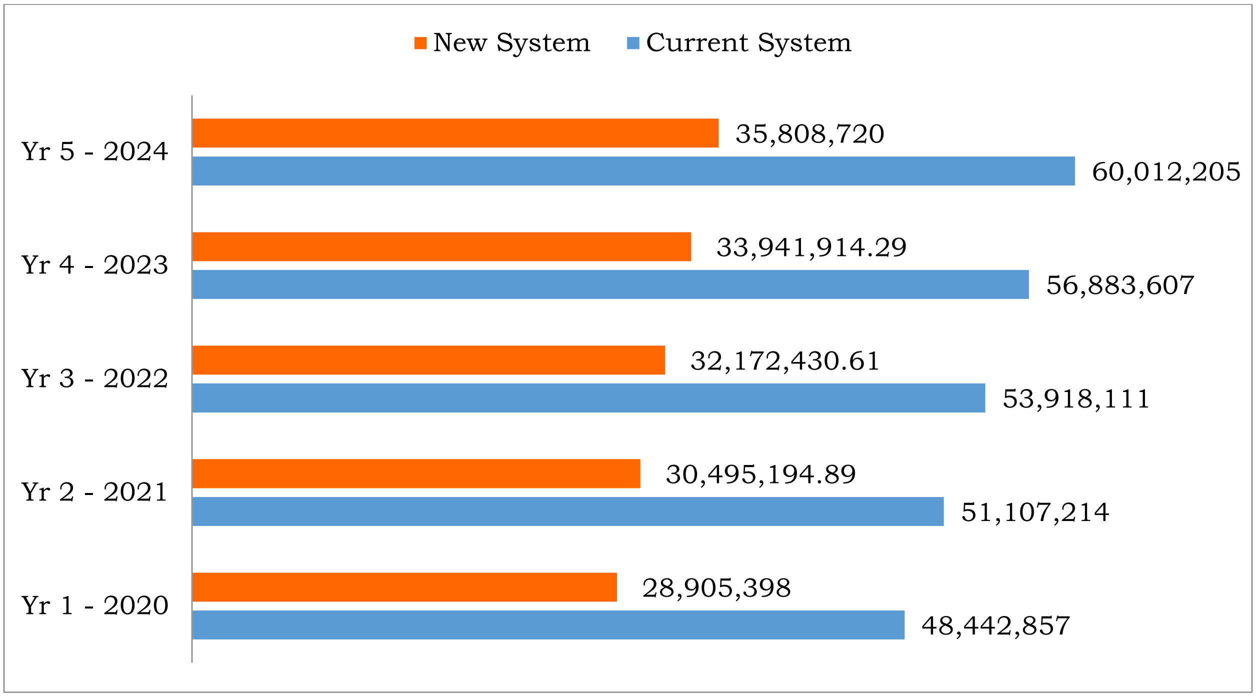

Figure 2. Trends of distribution costs between current and new model over 5 years.

This indicates that the cost of vaccine delivery form CVS to DVS would decrease by 37% once the system is modified by changing frequency and model of vaccine distribution.

Discussion

The current distribution system of vaccine in Rwanda is performing well with an average of 89% at all levels, as evidenced by absence of stock outs and expiries in past three years.[13] However, the program's performance is still heavily relying on external financial support where transport and distribution remain expensive which affect the sustainability of the program. Substantial amount of resources in the form of funds and time are spent on vaccine delivery due to the existing model and frequency of vaccine distribution system. The pull system with a frequency of 12 times a year, makes it costlier especially with respect to the time of health personnel dedicated to this activity. This is consistent with the study done in Benin and Mozambique, whereby redesigning the system reduced the cost and increased time for human resource in their systems to focus on other activities related immunization logistics other than distribution.[22]

The annual projections revealed that the cost will keep rising year after year, which would make it hard for the program to become sustainable. Redesigning the current Immunization supply chain management system considered to be efficient, will require an investment cost and difficult decision to be made. However, as shown in this study, changing the model from pull to push system, the operation cost will be reduced, although initial investment cost will always be high.[23]

This requires the primary level (CVS) to be ready and prepared to meet vaccine demand at the last mile taking into consideration potential distribution challenges between the secondary and third level (DHs and HCs). Keeping the vaccines availability ratio at high level would require the CVS to take care of the current available resources i.e. trucks which will be used to distribute vaccines as per the proposed grouping model. The most challenging and very sensitive activity or driver that would negatively affect and reduce the potential net savings is the "Preventive and Regular Maintenance" of the two existing trucks. However, available opportunities can be used without additional cost allocated to infrastructure at the beginning, which will ease the transition. Preventive and regular maintenance as estimated is another costed activity in addition to mission allowances and fuel. To ensure prompt vaccines availability, preventive and regular maintenance operating costs are secured and tailored to the program's annual budget which is currently applied since July 2020.

If the preventive maintenance estimated costs on annual basis is added to basic or regular drivers in the new distribution system design, the consolidated costs for delivering vaccines per year will still be far lower compared to the annual cost of delivering vaccines under the current distribution model. If the EPI is to use efficiently available resources (trucks) and deliver vaccines to secondary level, the program would save up to 37% of the current distribution costs. The cost may even keep decreasing if costed items are reduced like when the program decides to prepare packages properly for each DVS, label them and send the driver with products, would reduce the EPI staff budget as an additional cost savings.

Time spent by health workers (driver and EPI Focal person) during vaccines pick-ups or delivery will be another benefit since the time they spend during travels will be saved and can be dedicated to other activities like monitoring and evaluation of what is happening at last mile of vaccine delivery and supportive supervision to ensure quality of immunization supply chain and data visibility at the last mile.

This is a very significant cost that will result from redesigning the distribution frequencies and effective use of existing resources. If one is to compare the cost (in monetary terms) of the two distribution systems, it is quite clear that in a period of five years, if nothing is done to save on the distribution costs, the program will be far from achieving self-sustainability.

Conclusion

The study findings confirm a huge opportunity of getting the current vaccine distribution costs reduced when the distribution system is redesigned from pull to push from CVS to DVS and frequency from twelve to four per year.

With available resources (storage capacity at DVS and refrigerated trucks for transportation at CVS), the implementation of the redesigned system would contribute to financial sustainability of the vaccination program by a total cost saving of 37%.

Competing interests

The authors declare that they have no conflict of interests.

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Authors' contributions

EM coordinated the writing of the manuscript (design, data collection and analysis) as the main author. HS contributed to the review of the manuscript. SB contributed to manuscript design, data collection tool design and manuscript review as co-author. RH contributed to manuscript design, data analysis and review as co-author. MN contributed to manuscript design, data analysis and manuscript review as study main supervisor.

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