THINKWELL

Immunization Delivery Costs In Low- and Middle-Income Countries

A descriptive analysis, gap analysis, and summary of immunization delivery unit costs in the literature

April 2019

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ABBREVIATIONS

AEFI	Adverse event following immunization
BCG	Bacille Calmette-Guerin vaccine
DT	Diphtheria and tetanus toxoids, pediatric formulation
DTaP	Diphtheria and tetanus toxoids and acellular pertussis vaccine, pediatric formulation
DTP	Diphtheria and tetanus toxoids and whole-cell pertussis vaccine, pediatric formulation
FIC	Fully immunized child or full immunization of a vaccine (depending on situation)
HepB	Hepatitis B vaccine
Hib	Haemophilus influenzae type b
HPV	Human papillomavirus
ICAN	Immunization Costing Action Network
IDC	Immunization delivery cost
IDCC	Immunization Delivery Cost Catalogue
IPV	Inactivated poliovirus vaccine
JE	Japanese encephalitis
LMIC	Low- and middle-income country
MMR	Measles-Mumps-Rubella
MR	Measles-Rubella vaccine
NUVI	New and underutilized vaccine introduction
OCV	Oral cholera vaccine
OPV	Oral poliovirus vaccine
PCV	Pneumococcal conjugate vaccine
SIA	Supplementary immunization activity
Td	Tetanus and diphtheria vaccine, adult/adolescent formulation
TT	Tetanus toxoid
USD	U.S. dollar ($)
YF	Yellow fever

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This systematic review was conducted by ThinkWell and supported by the Bill & Melinda Gates Foundation.

WHAT IS THE PURPOSE OF THIS REPORT?

This report is intended to help with interpretation of the systematic review and to dig deeper into the variation in and drivers of immunization delivery costs across country contexts and immunization delivery strategies. The intended audience is national and sub-national planners and policymakers, researchers, and international partners supporting country immunization and health system policy.

WHAT IS THE IMMUNIZATION DELIVERY COST CATALOGUE (IDCC)?

The Immunization Delivery Cost Catalogue (IDCC) comprises the tools (Microsoft Excel workbook and web tool) created from the systematic review. The IDCC houses the most comprehensive, current, and standardized global evidence on the cost of delivering vaccines in low- and middle-income countries.

Access the online IDCC at

immunizationeconomics.org/ican-idcc

Research Question

The systematic review aimed to answer the question: What are the unit costs of vaccine delivery across different low- and middle-income countries (LMICs) and through a variety of delivery strategies?

Helping you answer questions like:

What is the cost per girl for HPV vaccination in schools?

OR

What is the cost per dose to deliver vaccines in health facilities in Sub-Saharan Africa?

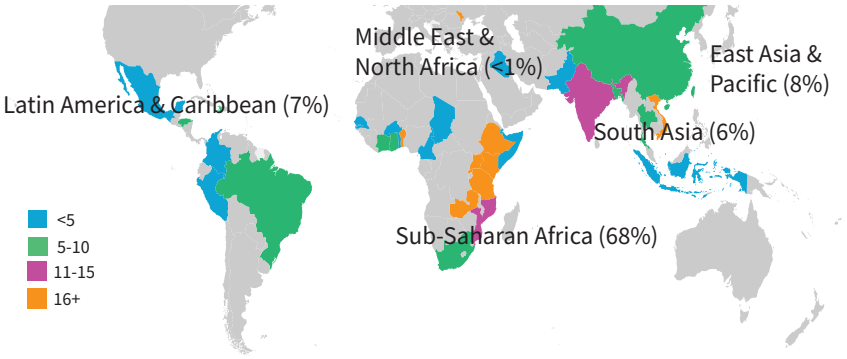
Who is it for?

National and sub-national planners and policymakers, researchers, and international partners supporting country immunization and health system policy. Data may be useful for budgeting, planning, policymaking, research, advocacy and beyond.

How to access it?

The catalogue is available online or in an Excel workbook. Other materials also available on website: summary report, methods note, user guides, how-to videos.

GEOGRAPHIC SPREAD (# of unit costs)

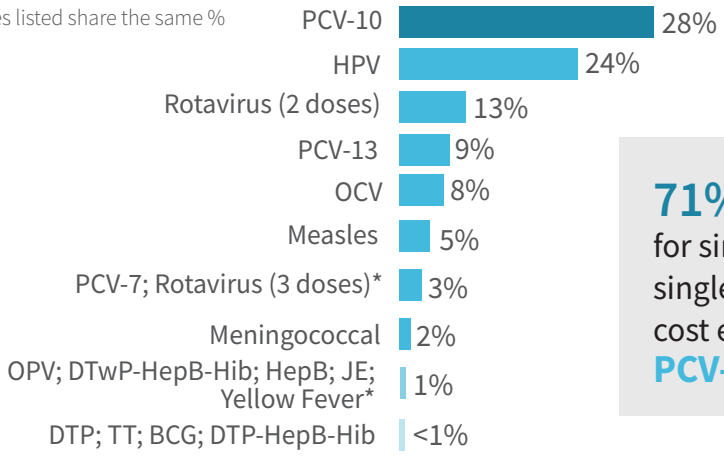


61
DATA SOURCES

410
IMMUNIZATION DELIVERY UNIT COSTS

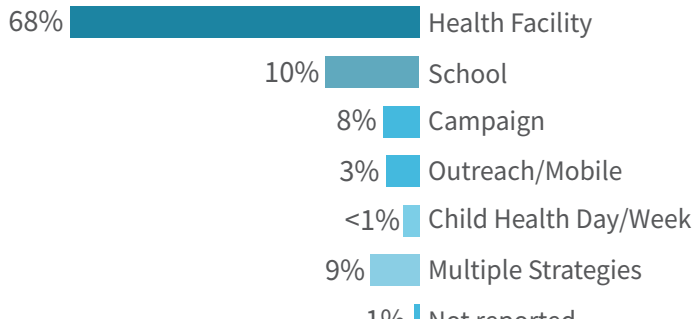
INCLUDED VACCINES (% of unit costs)

* Vaccines listed share the same %



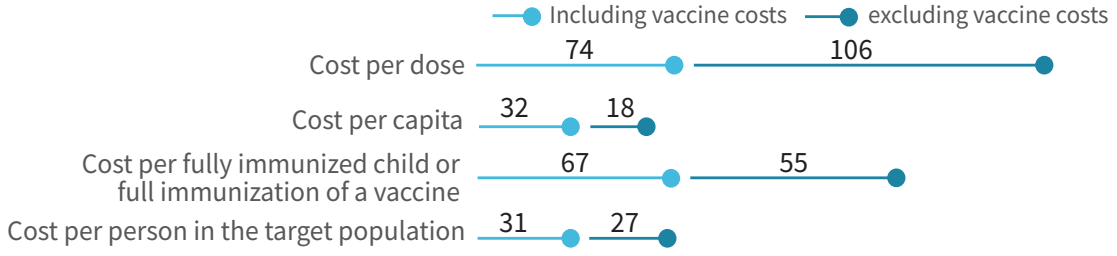
71% of the unit costs are for single vaccines. Of the single vaccines, most unit cost estimates are for **PCV-10** and **HPV**.

DELIVERY STRATEGIES (% of unit costs)



Over two-thirds of unit costs are for vaccines delivered at a health facility.

TYPES OF COSTS (# of unit costs)



I. INTRODUCTION

The Immunization Costing Action Network (ICAN), led by ThinkWell and John Snow, Inc. (JSI), is a research and learning community supported by the Bill & Melinda Gates Foundation (BMGF) with the aim of increasing the visibility, availability, understanding, and use of evidence on the cost of delivering vaccines.

Under the ICAN, ThinkWell conducted a systematic review to compile and analyze the evidence base on immunization delivery costs (IDCs) in low- and middle-income countries (LMICs). The Immunization Delivery Cost Catalogue (IDCC), available as an interactive Microsoft Excel workbook and searchable web tool, allows for comparability across numerous articles/reports (resources) and the variety of settings captured by the systematic review, with cost data presented in 2016 U.S. dollars.

This report briefly describes the systematic review and then presents a descriptive and gap analysis of findings on immunization delivery costs (IDCs). Additional tools and products, including a detailed methodology note and user guides, are accessible at **http://immunizationeconomics.org/ican**. These resources are intended to help with interpretation of the systematic review and to dig deeper into the variation in and drivers of IDCs across country contexts and delivery strategies.

Beyond the global level analytics, ICAN is conducting research studies on IDCs in India, Indonesia, Tanzania, and Vietnam, as well as facilitating cross-country learning on the common problems of costing immunization delivery and using evidence to inform advocacy efforts, routine planning and budgeting, and policy and program decision making. ICAN is also developing a methodological guide and costing tool to support the costing of vaccination campaigns.

THE NEED FOR ACCESSIBLE IMMUNIZATION DELIVERY COST EVIDENCE

As LMICs drive toward achieving high and equitable coverage of life-saving vaccines and largely transition from donor- to self-funded immunization programs, the availability of sustainable, equitable, and predictable financing for vaccine delivery is essential. Over the last two decades, great strides have been made in expanding the coverage of routine and new vaccines, in part through better understanding of the cost of vaccination delivery. However, gaps in cost evidence remain.

Realistic and reliable IDC evidence that is available at the right time and in the right format would help countries better advocate, plan, budget, and make programmatic decisions. Translation of cost evidence into policy, programming, and financing at national and sub-national levels is challenging. Cost data are fragmented and of variable quality, and can be difficult for policymakers, program planners, and other global and country-level stakeholders to understand and use. In an era of transitioning donor aid, the use of cost evidence in these processes, rather than historical funding levels or cost norms, is essential to ensuring that immunization programs mobilize adequate resources to meet coverage goals, address challenges of health equity, effectively manage the introduction of new vaccines, and achieve efficiencies through health system integration.

ICAN DEFINITION OF DELIVERY COSTS

The costs associated with delivering immunizations to target populations, exclusive of vaccine costs.
Delivery costs may include any or all of the following cost categories[1]:


Paid human resources


Volunteer human resources


Per diem and travel allowances


Cold chain equipment and their over-heads (e.g. energy, maintenance, repairs)


Vehicles, transport, and fuel


Program management


Training and capacity building


Social mobilization and advocacy


Adverse event following immunization (AEFI) and disease surveillance


Buildings, utilities, other overhead, and shared costs


Vaccine supplies (e.g. safety boxes, diluents, reconstitution syringes)


Waste management


Other supplies and recurrent costs


Other non-vaccine costs

Note: Cost categories used in this review were developed based on a review of Brenzel 2014, University of Washington 2016, and WHO 2006.

Additionally, as new delivery strategies – such as campaigns or school-based delivery – are explored to help countries meet these goals and the introduction of new vaccines, the need for cost evidence to develop and support these programmatic and budget requests is key. However, it can be time consuming and expensive to conduct country-specific costing studies. It also can be difficult to access and interpret cost evidence from other countries and to translate these data so they are relevant for other settings. To address these challenges, ThinkWell embarked on a systematic review to make the available evidence globally accessible and easy to interpret. The systematic review aimed to answer a question frequently asked by global and country immunization stakeholders: What are the unit costs of vaccine delivery across different LMICs and through a variety of delivery strategies? The initial systematic review, or Phase I, was completed in early 2018. The review was refreshed in 2018 to capture new content which is reflected in this report (Phase II). The systematic review and analyses will be refreshed again in 2019 to reflect new content and user feedback (Phase III).

PURPOSE OF THIS DOCUMENT

Past systematic reviews on this topic have consolidated only part of the costing evidence picture. They have focused on either (1) a subset of vaccines, (2) a subset of economic evaluations (e.g., only cost-effectiveness or cost-benefit studies), or (3) only the incremental costs of new vaccine introduction (NUVI). Given the latest published reviews and the large number of resources recently published on the topic of vaccine delivery costs, there was an expressed need to bring the evidence base up to date (De la Hoz-Restrepo et al. 2013; Levin et al. 2015; Mogasale et al. 2016; Ozawa et al. 2012). Our systematic review builds upon previous efforts, updating the evidence base while including IDC data that are not restricted to a particular vaccine, delivery strategy, type of cost analysis, or setting.

The review primarily targets country decision-makers: Expanded Programme on Immunization (EPI) managers, members of the National Immunization Technology Advisory Group (NITAG), and other country policymakers responsible for financing and planning at the national and the subnational levels. These decision-makers need to know what it costs to deliver a particular vaccine or range of vaccines in a particular context for budgeting the national immunization program or making a programmatic decision. Other target audiences include global and regional stakeholders, such as donors and development banks; other development partners; civil society organizations; and researchers. These groups may be interested in the systematic review and findings as reference data for making financing and resource allocation decisions or managing or supporting development programs, or for academic or applied research pursuits.

This report summarizes findings from the systematic review. First, the report presents a descriptive analysis of the dataset along with identified gaps in the evidence base. Second, the report presents an analysis of immunization delivery unit cost ranges (cost ranges) for vaccine delivery through a variety of strategies and in a variety of contexts.

Definitions
A full list of technical terms and definitions used in conjunction with the systematic review can be found on page 51 of this report.


स्वस्थ जीवन जिएं
बेटी बचाओ

II. SYSTEMATIC REVIEW OVERVIEW

The systematic review methods are based on standard practices and were subject to external review and revision by immunization costing experts at multiple stages throughout the process. The entire process is depicted in Figure 1 and is briefly described in the section that follows. The process is explained in detail in our methodology note (ICAN 2019).

The systematic review includes peer-reviewed articles and grey literature that included primary data collection and estimation of IDCs published between January 2005 and April 2018.[1] The review was limited to LMICs, resulting in 61 articles/reports (resources) that present immunization delivery unit costs (i.e., cost per dose, per capita, per fully immunized child, per full immunization of a vaccine,[2] and per person in the target population). Information extracted from the resources includes the reported cost results, along with methodological and contextual information to help with comparison and their interpretation. All cost findings are also converted to a common year (2016) and currency (U.S. dollars [US$]) to ensure comparability across studies and different settings. The quality of each resource is assessed against a parsimonious set of quality criteria[3] that capture methodological rigor and reporting standards, uncertainty of results, and risk of bias and limitations. Annex 1 presents the list of resources that are included in the review and that inform the analyses presented in this report.

[1] The date range for the systematic review was selected to reflect the most recent data, vaccine delivery technologies, and established costing methods for the sake of greater comparability, and to limit the size of the search. There are some seminal costing studies conducted prior to 2005, but these were excluded to capture resources using the most up-to-date and accepted methods to increase comparability of results (Brenzel, 2013; Castañeda-Orjuela et al. 2013). Many cost-effectiveness studies utilize cost estimates from secondary sources, leading to their exclusion. The methodology note (**immunizationeconomics.org/ican-idcc-methodology**) includes a detailed description of the search inclusion and exclusion criteria.
[2] Fully immunized child refers to the provision of required vaccines to a specific group by a clear point in time (e.g., infants who received all vaccines in the schedule before reaching one year of age). Full immunization of a vaccine refers to all required doses of a specific vaccine (e.g., three doses of HPV).
[3] See the methodology note at **immunizationeconomics.org/ican-idcc-methodology** for a detailed description of the quality assessment.

Our systematic review of **61** resources resulted in a dataset with **410** immunization delivery unit costs.

III. DESCRIPTIVE FINDINGS AND GAP ANALYSIS

The IDCC dataset presents information extracted from the resources as reported by the authors, along with cost information both as reported by the authors and then converted by us to 2016 US$. The cost data include immunization delivery unit costs (i.e., cost per capita, per dose, per full immunization of a vaccine, per fully immunized child, or per person in the target population). The IDCC dataset includes additional detail to help with interpretation of those costs, including information on study design, vaccines costed, delivery strategy, type of costs, and so on.

FIGURE 1. Process for systematic review

The descriptive and gap analysis describes the evidence on immunization delivery unit costs by focusing on three categories:

(1) Spread/scope of the evidence.

(2) Methods/reporting.

(3) Quality.

SPREAD OF EVIDENCE ON IMMUNIZATION DELIVERY UNIT COST FINDINGS

SOURCES OF IMMUNIZATION DELIVERY UNIT COST FINDINGS

Of the 61 resources, 56 are peer-reviewed articles and 5 are grey literature reports.

The majority of immunization delivery unit costs (70%) come from resources published from 2014 through 2016.

Nearly half (45%) of the unit costs come from the EPI Costing and Financing Project (EPIC), a multi-country immunization costing and financing project supported by the Bill & Melinda Gates Foundation.

GEOGRAPHIC SCOPE OF IMMUNIZATION DELIVERY UNIT COST FINDINGS

Country

The 410 immunization delivery unit costs include IDC data from a total of 33 LMICs (Figure 2). The largest number of unit costs (22%) come from Uganda. Six countries (Uganda, Benin, Moldova, Tanzania, Rwanda and Zambia) contributed nearly two-thirds of the unit costs (62%) in the dataset.[4] For eight countries (Burkina Faso, Chad, Indonesia, Iraq, Mexico, Togo, Pakistan, Senega), there exist two or fewer unit costs.

Country region

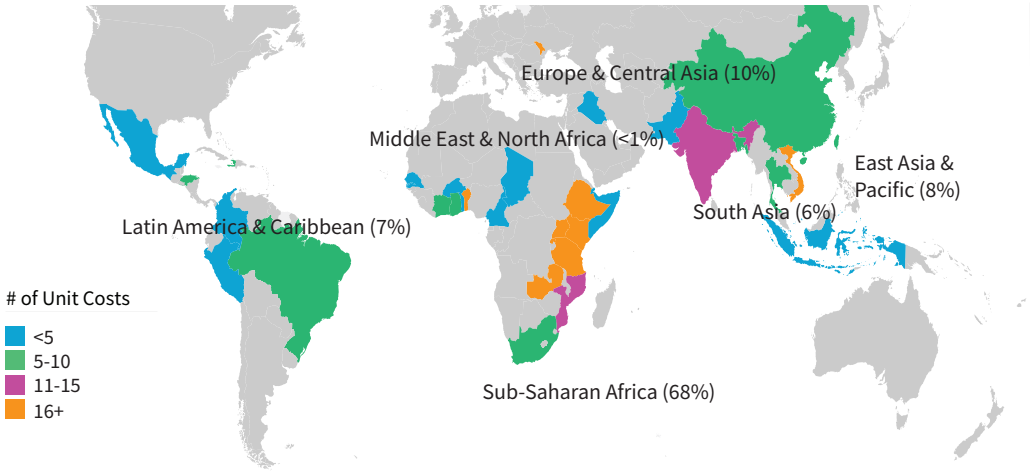
Sub-Saharan Africa accounts for more than two-thirds of all immunization delivery unit cost findings and Europe and Central Asia for one-tenth. There are fewer than 35 unit costs each for all other regions, including East Asia and Pacific (33), Latin America and the Caribbean (28), South Asia (26), and the Middle East and North Africa (2) (Figure 2).

Country income level

Over half of the unit costs (56%) are from low-income countries, and almost one-third (36%) are from lower-middle-income countries. Only 7% of the unit costs are from upper-middle-income countries (Figure 2).

[4] **http://www.immunizationeconomics.org/epic**

FIGURE 2. Geographic scope of immunization delivery unit cost findings



Distribution by Country Income Level

Low income (56%) | Lower middle income (36%) | Upper middle income (7%)

Country	Unit Costs (#)
Uganda	89
Benin	42
Moldova	42
Tanzania	35
Rwanda	24
Zambia	23
Vietnam	19
Ethiopia	14
India	14
Mozambique	11
Ghana	8
Cote d'Ivoire	7
Honduras	7
South Africa	6
Bangladesh	6
Haiti	6
Thailand	6

Country	Unit Costs (#)
China	6
Brazil	5
Bhutan	5
Kenya	5
Cameroon	4
Colombia	4
The Gambia	4
Peru	4
Burkina Faso	2
Chad	2
Indonesia	2
Iraq	2
Mexico	2
Togo	2
Pakistan	1
Senegal	1

Notes: Country regions and income levels use the World Bank classification. The analysis aims for consistency with the context of each resource included in the review, matching the year for which the costing data were reported with the country's regional and income classification of that same year. If the costing year was not reported, the year of the intervention was used. If that was also not available, the publication year of the resource was used.

Gap analysis:

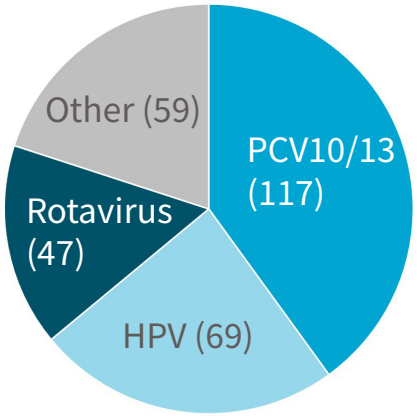
There is no IDC data from the overwhelming majority of LMICs (103/137 countries, 75%). Evidence is limited from all regions other than Sub-Saharan Africa and East Asia and the Pacific. Considering country income level, the greatest need for cost data is from upper-middle-income countries.

VACCINES COSTED

Single Vaccines

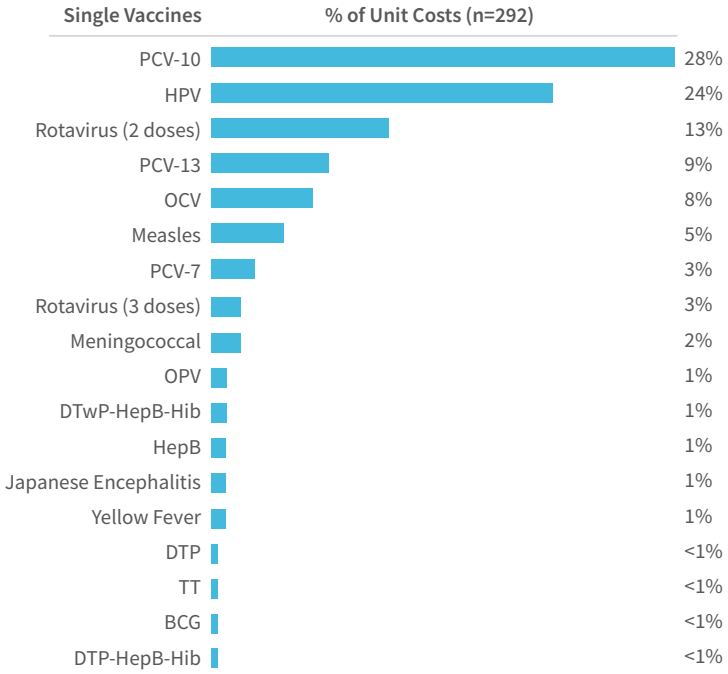
Nearly three-fourths of the immunization delivery unit costs are costs for single vaccines (Figure 3).

Of the costs for single vaccines, 84% are in the context of new vaccine introduction.



Of the single vaccines, most immunization delivery unit costs are for PCV (40%), HPV (24%), and Rotavirus (16%).

FIGURE 3. Distribution of immunization delivery unit cost findings for single vaccines



Notes: Percentages do not sum to 100% due to rounding. There were no resources with immunization delivery unit costs for Inactivated Poliovirus Vaccine (IPV).

Codes: BCG = Bacillus Calmette-Guérin; DTP = Diphtheria and tetanus toxoids and whole-cell pertussis vaccine, pediatric formulation; HepB = Hepatitis B; Hib = Haemophilus influenzae type b; HPV = Human Papillomavirus; JE = Japanese Encephalitis; OCV = Oral Cholera Vaccine; OPV = Oral Polio Vaccine; PCV = Pneumococcal Conjugate Vaccine (7-, 10-, or 13-valent); TT = Tetanus Toxoid

Multiple vaccines and vaccine schedules

Less than one-third (29%) of the immunization delivery unit costs are associated with delivery of more than one vaccine or a schedule of vaccines. Since there are numerous vaccine schedules represented, they are considered in terms of both number of antigens as well as number of contacts with the health system (Figures 4 & 5).

Almost three-fourths (71%) of the unit costs are from schedules that contain between five and nine antigens (Figure 4).

Notes: The unit costs associated with multiple vaccines or schedules of vaccines represent between four and ten contacts with the health system. Unlike the number of costed antigens, which only describes which antigens are administered, the number of contacts with the health system reflects co-administration, which may result in delivery cost savings. For example, a schedule including BCG, Measles, DTP-HepB-Hib, OPV, and YF includes five antigens and five contacts with the health system (i.e., contacts are approximately birth, 2 months, 4 months, 6 months, and 9 months). The majority of immunization delivery unit cost findings (56%) are for schedules that require between five and eight contacts with the health system (Figure 5).

FIGURE 4. Antigens costed for multiple vaccines and vaccine schedules

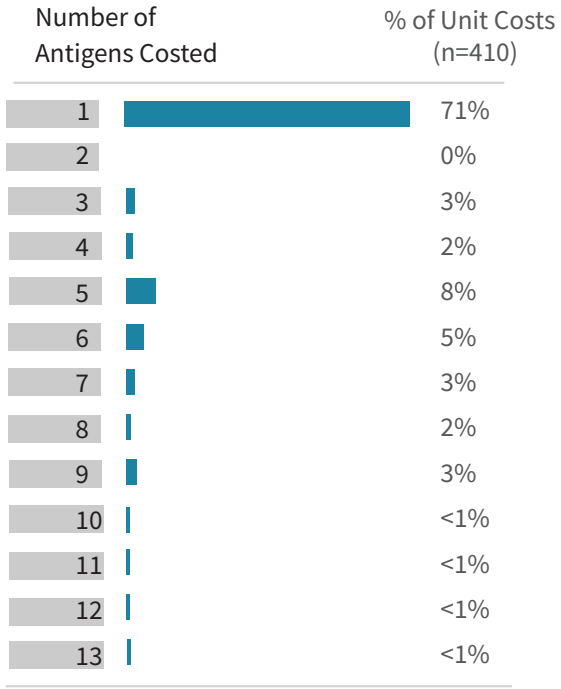
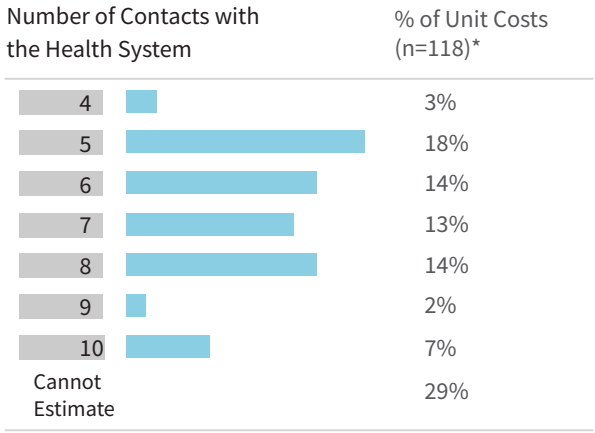


FIGURE 5. Contacts with the health system for multiple vaccines and vaccine schedules



*Number of unit costs only including between 4 and 10 contacts with the health system.

Notes: Percentages do not sum to 100% due to rounding. "Cannot estimate" means that the number of contacts with the health system could not be determined because of lack of information about vaccination timing (for example, in the case of vaccines for high-risk groups or those given only in outbreak situations) or due to limitations in the write-up of the resource.

Gap analysis:

Except for PCV, HPV, and Rotavirus, limited immunization delivery unit cost data exist on all other single vaccines. For unit costs reporting on multiple vaccines or vaccine schedules, there is high variability in antigens and number of contacts with the health system, making it challenging to compare across them.

DELIVERY STRATEGIES

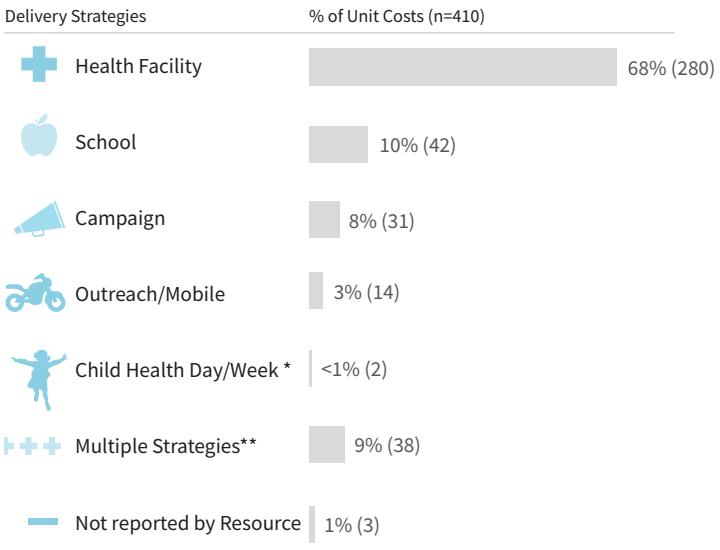
280 130

Over two-thirds of the unit costs pertain to health facility delivery,[6] reflecting the predominant delivery of vaccines at fixed sites.

42 368

There are also a substantial number of unit costs for school-based delivery (10%), all published since 2010 and focused on HPV introduction.

FIGURE 6. Immunization delivery unit costs by delivery strategy

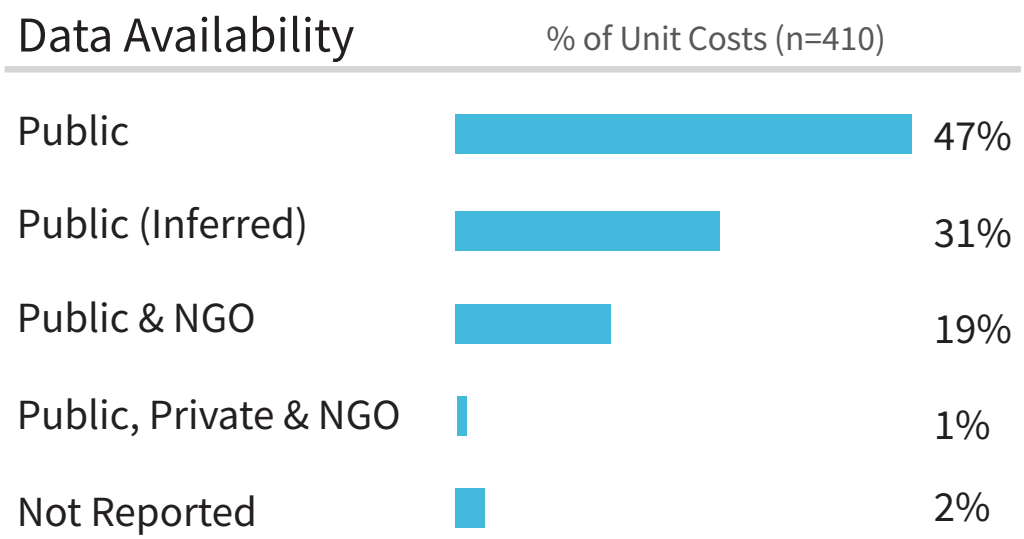


* Includes child health days/weeks or national immunization days/weeks.
** Refers to a combination of two or more delivery strategies.

[6] Some deliveries reported by articles/reports as "health facility" may also include delivery via outreach/mobile or other strategies primarily due to how data are recorded by the health facility.

DELIVERY SECTOR

FIGURE 7. Immunization delivery unit costs by delivery sector



Gap analysis:

Limited data exist on the cost of delivery at private and NGO facilities.

TARGET DELIVERY POPULATIONS

The immunization delivery costs cover a range of target delivery populations, from birth to older children/ adolescents, to other groups, such as pregnant women.

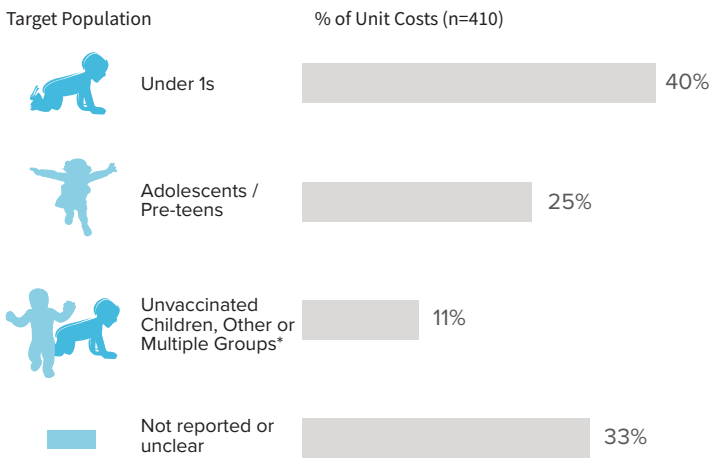
163 247

40% of the unit costs are for delivery to under ones (birth cohort, newborns, and infants).

69 341

Almost one-fifth (17%) of the unit costs are for delivery to adolescents/pre-teens, which includes 10-year-old girls and older children/ adolescents (Figure 8).

FIGURE 8. Target population for immunization delivery



*The category "Other or multiple groups" includes a number of other age ranges, (e.g., under 5s, 2- to 3-year-olds, 6 months to less than 10-year-olds, cholera high-risk individuals, hard-to-reach children, healthy non-pregnant individuals, and combinations of target populations).

Gap analysis:

More thorough reporting is needed to clearly identify the target delivery population, as it was unidentified for almost one-third (32%) of the unit costs.

NEW VACCINE INTRODUCTIONS

Nearly two-thirds of the unit costs relates to new vaccine introduction.

Most (86%) of the unit costs on new vaccine introductions represent vaccines costed incrementally.

27% of unit costs on new vaccine introduction costed the introduction of HPV vaccine.

TABLE 1. New vaccines costed incrementally for introduction

Vaccines	# of unit costs
Incremental costs	
HPV	69
PCV-10	80
Rotavirus (2 doses)	38
PVC-13	27
PCV-7	9
Rotavirus (3 doses)	8
Measles	5
Measles Rotavirus (2 doses) PCV-10	4
Measles Rotavirus (2 doses) PCV-13	4
OCV	3
BCG Measles DTP TT OPV JE	2
BCG Measles Hepb DTP TT OPV	2
JE	2
DTwP-HepB-Hib	2
BCG Measles Hepb TT OPV	1
BCG Measles TT DTP-HepB-Hib OPV PCV7 YF	1
BCG Measles TT DTP-Hib OPV	1
DTP-HepB-Hib	1
HepB	1
Total	**260**

Gap analysis:

There are limited data on the incremental costs of introducing vaccines other than the HPV and pneumococcal vaccines.

METHODS/REPORTING OF EVIDENCE ON IMMUNIZATION DELIVERY UNIT COSTS

STUDY PERSPECTIVE

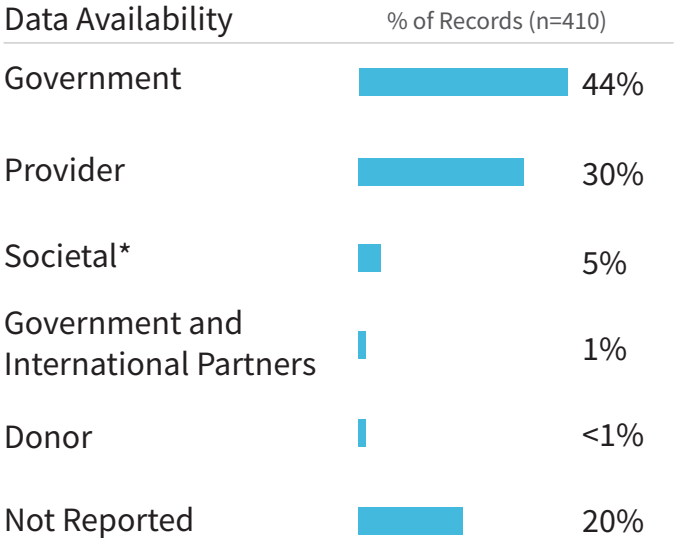
330 80

The study perspective taken is noted for over three-quarters of unit costs.

304 106

The largest share of unit costs is from costing studies that took a government (44%) or provider perspective (30%) (Figure 9).

FIGURE 9. Immunization costing study perspective



Notes: In most cases, where societal perspective was reported by the resource, the methodology section clarified that in fact a government or provider perspective was taken. Perspective noted in the IDCC is as reported by the resource.

Gap analysis:

The largest gap is the lack in reporting or inaccurate reporting of the perspective taken. Immunization delivery unit costs associated with an unreported perspective are likely to be government/provider. Unit costs associated with the societal perspective were defined as such by resource authors, but were often determined by the research team to be a government or provider perspective.

STUDY DESIGN

220 190

Over half (54%) of the unit costs are based on a retrospective study design.

170 240

Almost half (41%) of the unit costs are based on a prospective design.

COST METHODOLOGY

Almost two-thirds (66%) of immunization delivery unit costs are based on the ingredients approach. 10% are based on bottom-up, top-down, micro-costing, mixed, or micro-costing and ingredients approaches.

Gap analysis:

Clearer reporting that identifies the cost methodology used is needed as 14% of immunization delivery unit costs are from resources that did not report or did not clearly report on the cost methodology used

TYPES OF COSTS

More than half (60%) of the unit costs are incremental delivery costs, compared with 34% that are full costs. Half (49%) of the unit costs represent economic costs, one-third (32%) financial costs, and only 11% fiscal costs. Most unit costs are incremental economic costs (26%), followed by full economic costs (21%), and then incremental financial costs (20%) (Table 2).

Definitions

Economic costs: Financial outlays plus opportunity costs, such as heath worker time and any donated items such as vaccines
Financial costs: Financial outlays, usually with straight-line depreciation of capital items
Fiscal costs: Financial outlays, usually without depreciation of capital items

TABLE 2. Type of cost by economic, financial, and fiscal costs

Type of Costing	Type of Unit Costs				Total Unit Costs
	Economic	Financial	Fiscal	Not reported/ unclear	
Full Costing	87 (21%)	29 (7%)	0 (0%)	18 (4%)	140 (34%)
Incremental Costing	108 (26%)	84 (20%)	46 (11%)	8 (2%)	246 (60%)
Not Reported	4 (1%)	20 (5%)	0 (0%)	0 (0%)	24 (6%)
Total Unit Costs	199 (49%)	113 (32%)	46 (11%)	26 (6%)	410 (100%)

Note: Percentages do not sum to 100% due to rounding.

Gap analysis:

For a considerable number of unit costs, the type of cost is unclear or is not reported in the resource. There are gaps in both financial and fiscal costs, which are likely most useful for country-level planners and policymakers.

IMMUNIZATION DELIVERY UNIT COSTS

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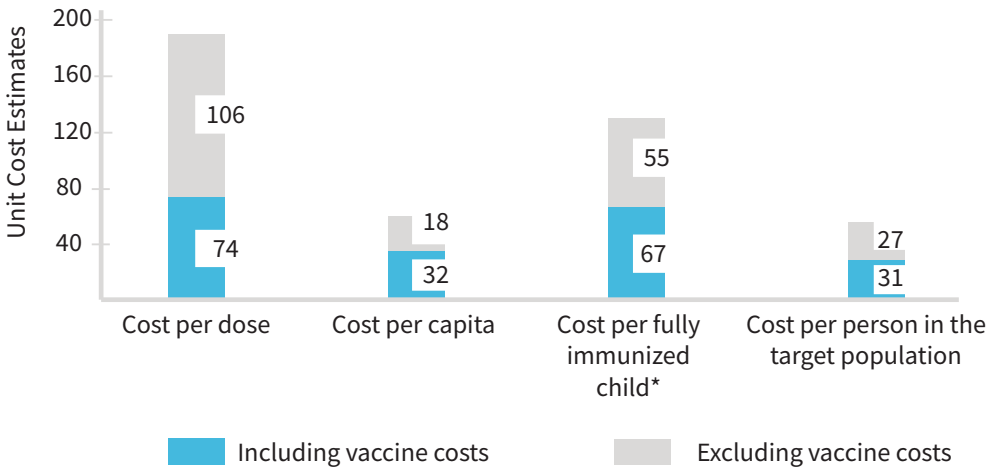
Slightly more immunization delivery unit costs exclude the vaccine cost (50.2%), compared to the immunization delivery unit costs that include vaccine cost (49.8%).

Gap analysis:

There are major gaps in the inclusion of relevant cost categories, including:
(1) adverse event following immunization (AEFI) and disease surveillance; (2) buildings, utilities, other overheads and/or shared costs; (3) per diem and travel allowances; (4) program management; and (5) waste management.[9]

FIGURE 10. Typology of immunization delivery unit costs in dataset



Cost per dose is the most frequently reported immunization delivery unit cost (44%), followed by cost per full immunization of a vaccine or fully immunized child[10] (30%), cost per person in the target population (14%), and cost per capita (12%).

Notes: *Cost per full immunization of a vaccine or fully immunized child.

[9]Note that some cost categories, such as volunteer human resources and some shared costs, may be justifiably excluded in financial and fiscal cost analyses, so their exclusion from the immunization delivery unit cost estimates would not represent a gap.
[10] Fully immunized child refers to the provision of required vaccines to a specific group by a clear point in time (e.g., infants who received all vaccines in the schedule before reaching one year of age). Full immunization of a vaccine refers to all required doses of a specific vaccine (e.g., three doses of HPV).

COST CATEGORIES[8]

The majority of immunization delivery unit costs include the major cost drivers of vehicles, transport, and fuel (98%); cold chain equipment and overheads (88%); paid human resources (80%); and vaccine supplies (79%) (Table 3). The most commonly included cost category was vehicles, transport, and fuel. In contrast, volunteer human resources and adverse event following immunization (AEFI) and disease surveillance were the least commonly included costs, included in only 9% and 24% of the unit costs, respectively.

Most immunization delivery unit costs (82%) include half of the cost categories (8 of 14 cost categories). Over half (51%) of unit costs include 10 or more cost categories. Fourteen percent of the unit costs are comprised of only supply chain costs (three to six cost categories of 14).

TABLE 3. Cost category inclusion by costing type

Cost category	Economic (n=199)	Financial (n=133)	Fiscal (n=46)	Total (n=410)
Paid HR	90%	54%	100%	80%
Volunteer HR	17%	2%	0%	9%
Per diem & travel allowances	59%	59%	48%	59%
Cold chain equipment & overheads	91%	77%	100%	88%
Vehicles, transport & fuel	98%	98%	100%	98%
Program management	40%	55%	22%	42%
Training & capacity building	71%	89%	87%	77%
Social mobilization & advocacy	69%	91%	87%	77%
Adverse event monitoring	23%	28%	0%	24%
Buildings, utilities, other overheads & shared costs	57%	32%	100%	53%
Vaccines	83%	64%	91%	77%
Vaccine supplies	75%	85%	91%	79%
Waste management	38%	68%	52%	50%
Other supplies & recurrent costs	51%	44%	100%	51%
Other category costs	59%	30%	39%	46%

Notes: *Volunteer human resources are likely only to be possibly included in economic costing resources; of the unit costs reporting economic costs, 17% include volunteer human resources.

[8] Cost categories used in this review were developed based on review of Brenzel 2014, University of Washington 2016, and WHO 2006.

IV. QUALITY ASSESSMENT OF EVIDENCE ON IMMUNIZATION DELIVERY UNIT COSTS

The quality of each resource was assessed on three dimensions: methodological rigor and reporting standards (8 items), uncertainty of results (3 items), and risk of bias and limitations (3 items) (Table 4). Each item was given an individual score of 1 (lowest), 2, or 3 (highest); for some items there was also a "not applicable" option.

Scores for all items were summed and averaged, excluding any "not applicable" answers, to produce a final score for each resource on the same 1 to 3 scale. For more information on the quality assessment, refer to the methodology note at immunizationeconomics.org/ican-idcc-methodology.

The overall mean quality score across the 60[11] resources is 2.2 (Figure 11).

The two assessment categories with the highest mean score are "Contextual factors: are there any contextual factors related to the study setting that have not been accounted for in the results?" (2.9/3.0), meaning that resources that reported contextual factors took them into account in the results, and "Replicability: was the purpose of the study clearly defined?" (2.9/3.0) (Table 3). One other category scored especially high as well: "Accuracy of reported findings: does sum of capital and recurrent items match total?" (2.7/3.0).

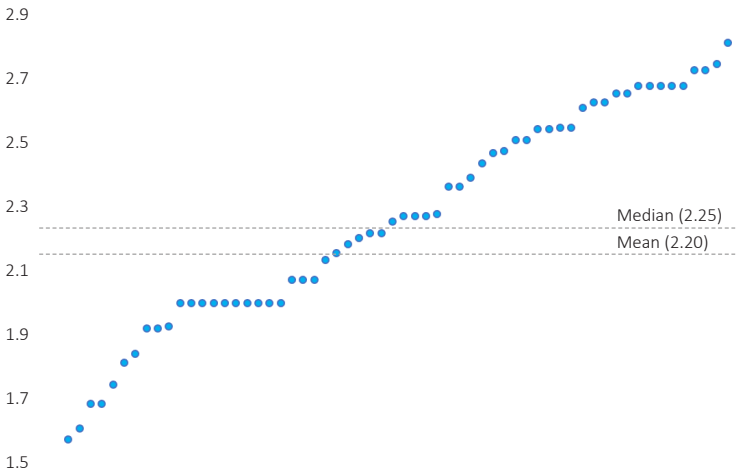
TABLE 4. Quality assessment scoring

Quality Attribute	Mean Score*
Methodology and reporting	
Quality of input data/data source	2.4
Sample strategy in relation to conclusion and generalizability	2.6
Data analysis strategy	1.1
Allocation of shared costs	1.8
Annualization of capital items	1.8
Replicability: methods	2.0
Replicability: study purpose	2.9
Reporting of results	2.3
Accuracy of reported findings: Does sum of capital and recurrent items match total?	2.7
Accuracy of reported findings: Does sum of cost categories match total?	2.4
Uncertainty of results	
Sensitivity analysis	1.3
Missing cost categories	2.5
Contextual factors	2.9
Risk of bias/limitations	
Author-stated limitations	2.1
Extractor-perceived limitations	2.4
Overall Total	**2.2**

Notes: *Resources scoring n/a were not included in mean calculations; see methodology note for more information.

[11] One resource of the 61 was a dataset and personal communication with the EPIC costing team. This was not included in the quality assessment.

FIGURE 11. Quality assessment scores by article/ report[12]



The category with the lowest score is "Data analysis strategy: were statistical tests used and confidence intervals reported?" (1.1/3.0), indicating that the overwhelming majority of resources did not report sufficient methodological detail in this area. A category that also scored low (1.3/3.0) is "Sensitivity analysis: if done, did the sensitivity analysis include all reasonable scenarios affecting costing results?"

[12]The x-axis represents the resources, sorted by score. Each dot represents a single resource's score.

Gap analysis:

Much better methods reporting is needed, particularly with regard to data analysis strategy and sensitivity analyses.

V. IMMUNIZATION DELIVERY UNIT COST RANGES

The analyses on the 2016 US$ immunization delivery unit costs (cost per dose, per capita, per full immunization of a vaccine or fully immunized child, per person in the target population) led to the development of immunization delivery cost ranges (cost ranges) for specific vaccines, by different delivery strategies, and for different country contexts. To generate the most robust estimates, results are based on four or more comparable immunization delivery unit costs. Results are primarily presented as cost ranges, rather than as single point estimates, to emphasize the variability in costing results related to context, costing methods, and reporting. Delivery cost variation is important for potential users to consider. The IDCC can be explored further to determine underlying reasons for cost variation.

Cost ranges were generated according to the following five steps:

1. Identification of immunization delivery unit costs that are methodologically and contextually similar, based on four to seven mandatory comparability criteria, considering type of cost, delivery platform and scale and other factors (Annex 3).

2. Checking comparability of unit costs against an additional set of methods, vaccine delivery and contextual criteria.

3. Calculation of cost ranges for combinations of four or more comparable immunization delivery unit costs with associated descriptive statistics, including the range (minimum and maximum), mean, median, and 25th and 75th percentile estimates.

4. Validation of cost ranges with a panel of immunization costing experts.

5. Preparation of methodological notes to facilitate interpretation.

The methods for each step are described in detail in the companion methodology note at **immunizationeconomics.org/ican-idcc-methodology.**

[13] See page 23 for definitions of economic, financial and fiscal costs.

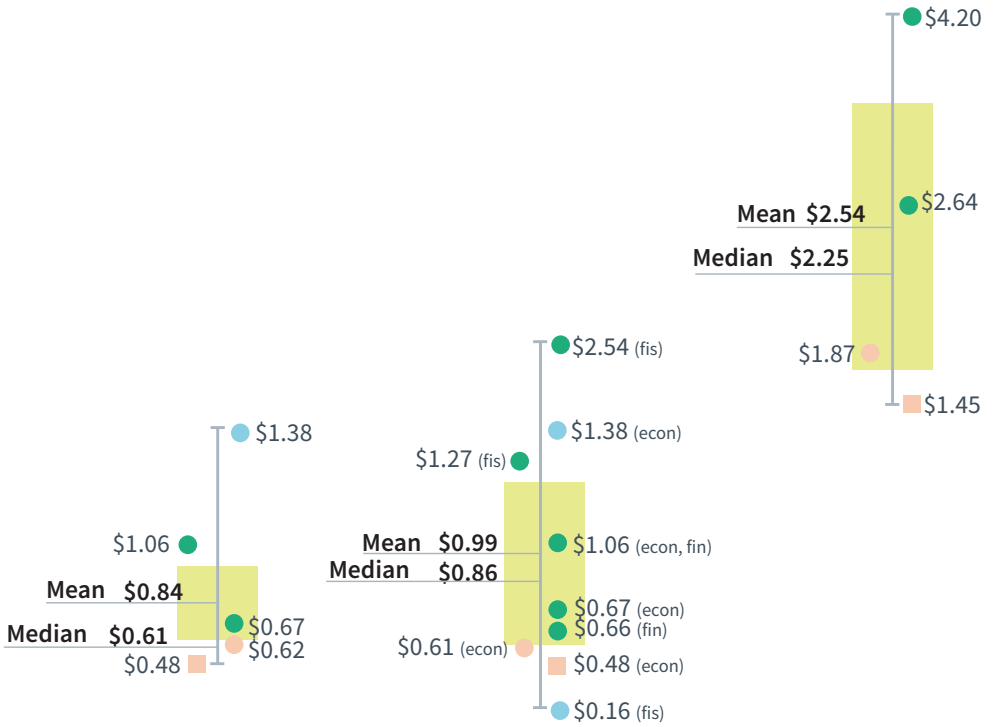
[14] "Multiple strategies" refers to delivery of two or more strategies in combination (i.e., health facility, school, outreach/mobile, campaign, and/or child health day/week or national immunization day/week).

VI. IMMUNIZATION DELIVERY UNIT COST ESTIMATES

The three figures depicting the eight immunization delivery unit cost ranges (cost ranges) are displayed alongside the accompanying tables on the next three pages (pp. 31-35). Annex 4 explains how to interpret these figures.

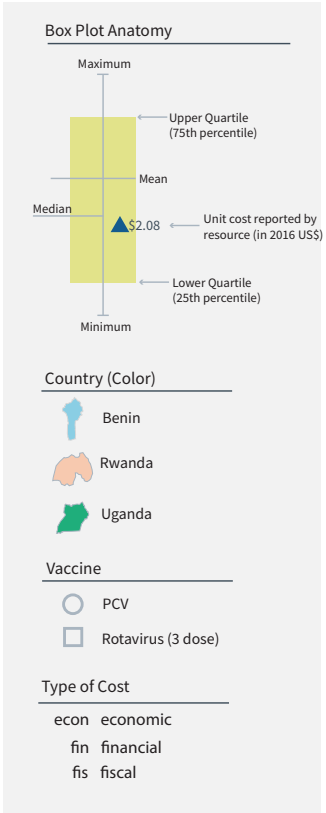
IMMUNIZATION DELIVERY UNIT COST RANGES 1-3

Incremental cost of single, newly introduced vaccines, excluding vaccine cost (2016 US$)



UNIT COST (excluding vaccine cost)	Economic cost per dose	Economic, financial and fiscal cost per dose	Economic cost per full immunization of a vaccine (3 doses)
DELIVERY STRATEGY	Health facility (fixed site) (routine delivery, not SIA)		
OTHER COST DETAILS	Includes both introduction/startup costs and recurrent/ongoing costs		

KEY



ADDITIONAL DETAIL: INCREMENTAL COST RANGE FOR SINGLE, NEWLY INTRODUCED VACCINES (EXCLUDING VACCINE COSTS) (2016 US$)

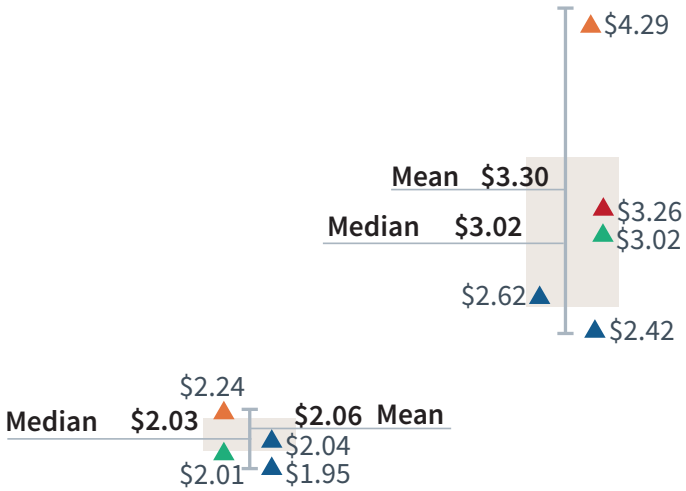
No.	Countries	Vaccines costed	Delivery strategy (platform)	Delivery sector	Delivery scale	Other notes for interpretation	Quality score of	No. of cost categories (of 14)**	Type of unit cost+	Individual immunization delivery unit costs	Immunization delivery cost range (2016 US$)	Descriptive statistics (2016 US$)
1	Benin, Rwanda, Uganda (Low-income countries in sub-Saharan Africa)	PCV7/10/13 & Rotavirus (3 dose)	Health facility (fixed site) (Routine delivery, not SIA)	Public sector and NGO	National	The Rwanda unit costs are based on a sample of 3 facilities, while the other estimates had samples of 49 facilities	2.1-2.7	10-12 (all major cost categories included)	Economic cost per dose	$0.48 (Rota, Rwanda)[1] $0.62 (PCV, Rwanda)[1] $0.67 (PCV, Uganda)[2] $1.06 (PCV, Uganda)[2] $1.38 (PCV, Benin)[3]	$0.48 - $1.38	**Mean: $0.84** 25th percentile: $0.62 **Median: $0.61** 75th percentile: $1.06
2	Benin, Rwanda, Uganda (Low income countries in sub-Saharan Africa)	PCV7/10/13 & Rotavirus (3 dose)	Health facility (fixed site) (Routine delivery, not SIA)	Public, public and NGO, not reported	National	The Uganda unit costs come from a single source	2.5-2.7	8-12 (all major cost categories included)	Economic, financial, and fiscal cost per dose	$0.16 (PCV, Benin, fis.)[3] $0.48 (Rota 3 dose, Rwanda, econ.)[1] $0.61 (PCV, Rwanda, econ.)[1] $0.66 (PCV, Uganda, fin.)[2] $0.67 (PCV, Uganda, econ.)[2] $1.06 (PCV, Uganda, econ.)[2] $1.06 (PCV, Uganda, fin.)[2] $1.27 (PCV, Uganda, fis.)[2] $1.38 (PCV, Benin, econ.)[3] $2.54 (PCV, Uganda, fis.)[2]	$0.16 - $2.54	**Mean: $0.99** 25th percentile: $0.62 **Median: $0.86** 75th percentile: $1.22
3	Rwanda, Uganda (Low-income countries in sub-Saharan Africa)	PCV7/10 & Rotavirus (3 dose)	Health facility (fixed site) (Routine delivery, not SIA)	Public sector, public sector and NGO	National	The Rwanda unit costs are based on a sample of 3 facilities, while the other estimates had samples of 49 facilities	2.1-2.7	10-12 (all major cost categories included)	Economic cost per full immunization of a vaccine (3 doses)	$1.45 (Rota, Rwanda)[1] $1.87 (PCV, Rwanda)[1] $2.64 (PCV, Uganda)[2] $4.20 (PCV, Uganda)[2]	$1.45 - $4.20	**Mean: $2.54** 25th percentile: $1.77 **Median: $2.25** 75th percentile: $3.03

*The quality of each article/report was assessed using a checklist developed by the ICAN research team. The quality scores across all articles/reports ranged from 1.6 to 2.8, with an average (mean) score of 2.2.
**The ICAN research team considered paid HR, cold chain equipment and overheads, vehicles, transport, and fuel, and training and capacity building to be the major cost categories.
+ Includes both introduction/startup costs and recurrent/ongoing costs.

References:
[1] Ngabo, F., Levin, A., Wang, S. A., Gatera, M., Rugambwa, C., Kayonga, C., … Hutubessy, R. (2015). **A cost comparison of introducing and delivering pneumococcal, rotavirus and human papillomavirus vaccines in Rwanda. Vaccine, 33(51), 7357–7363. https://doi.org/10.1016/j.vaccine.2015.10.022**
[2] Guthrie, T., Zikusooka, C., Kwesiga, B., Abewe, C., Lagony, S., Schutte, C., … Kinghorn, A. (2014). **Costing and Financing Analyses of Routine Immunization in Uganda.**
[3] **AMP. (2014). Costing and financing analyses of routine immunization and new vaccine introduction in Benin Final Report.**

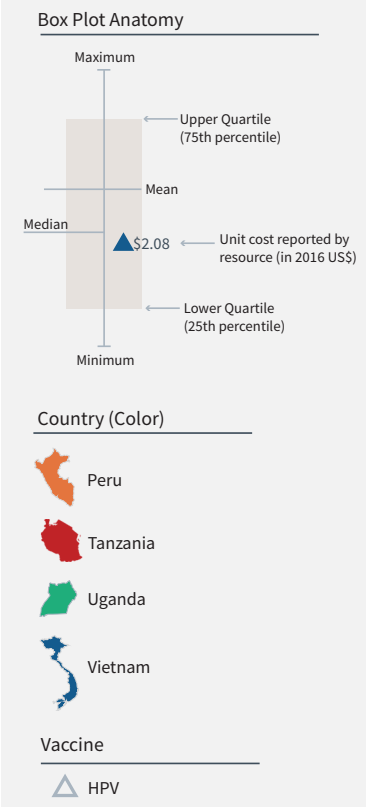
IMMUNIZATION DELIVERY UNIT COST RANGES 4-5

Incremental cost of introducing HPV vaccine to an existing schedule, excluding vaccine cost (2016 US$)



UNIT COST (excluding vaccine cost)	Financial cost per dose	Economic cost per dose
DELIVERY STRATEGY	School (routine delivery, not SIA) (costs are related to pilot/project delivery)	Health facility, school (routine delivery, not SIA) (costs are related to pilot/project delivery)
OTHER COST DETAILS	Includes both introduction/startup costs and recurrent/ongoing costs	

KEY



ADDITIONAL DETAIL: INCREMENTAL COST RANGE FOR HPV VACCINE (EXCLUDING VACCINE COSTS) (2016 US$)

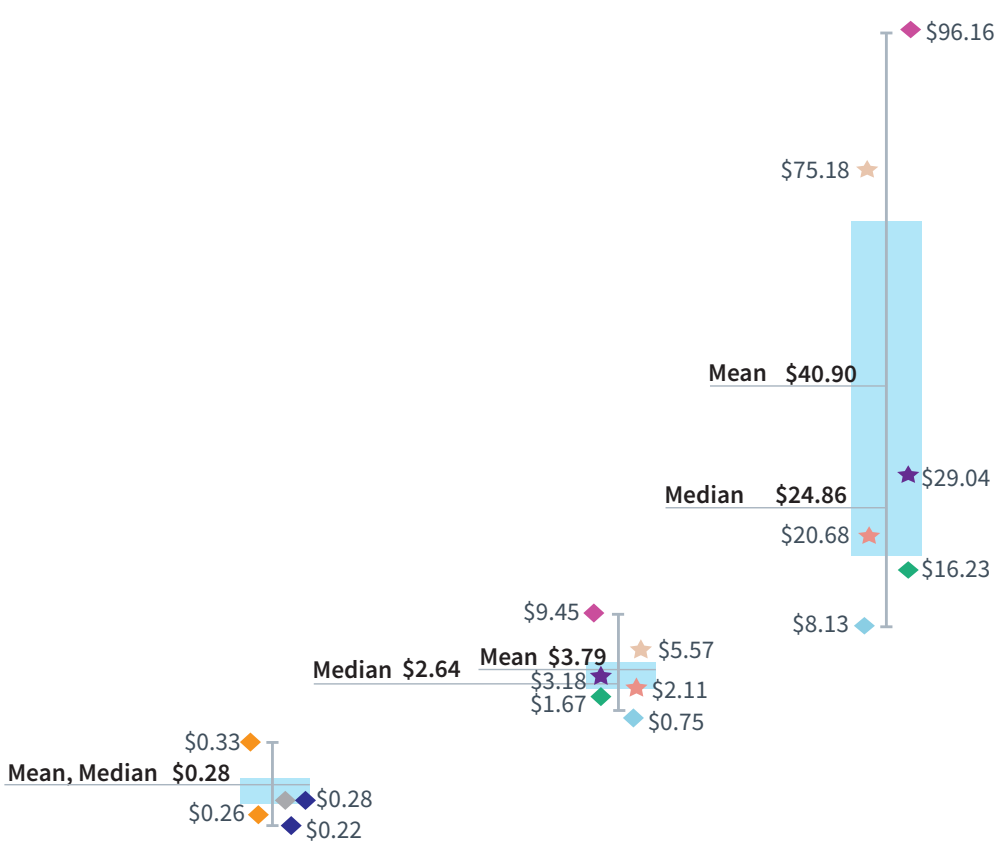
No.	Countries	Vaccines costed	Delivery strategy (platform)	Delivery sector	Delivery scale	Other notes for interpretation	Quality score of resources*	No. of cost categories (of 14)**	Type of unit cost+	Individual immunization delivery unit costs	Immunization delivery cost range (2016 US$)	Descriptive statistics (2016 US$)
4	Peru, Tanzania, Uganda, Vietnam	HPV	School (Routine delivery, not SIA)	Public sector	Pilot/ project	A single resource was used to generate the cost range	2.0	7 (all major cost categories included)	Financial cost per dose	$1.95 (Vietnam)[1] $2.01 (Uganda)[1] $2.04 (Vietnam)[1] $2.24 (Peru)[1]	$1.95 - $2.24	**Mean: $2.06** 25th percentile: $2.00 **Median: $2.03** 75th percentile: $2.09
5			Health facility and school (Routine delivery, not SIA)			Two resources were used to generate the cost range	2.0-2.5	8-12 (all major cost categories included except cold chain)	Economic cost per dose	$2.42 (Vietnam)[1] $2.62 (Vietnam)[1] $3.02 (Uganda)[1] $3.26 (Tanzania)[2] $4.29 (Peru)[1]	$2.42 - $4.29	**Mean: $3.30** 25th percentile: $2.62 **Median: $3.02** 75th percentile: $3.26

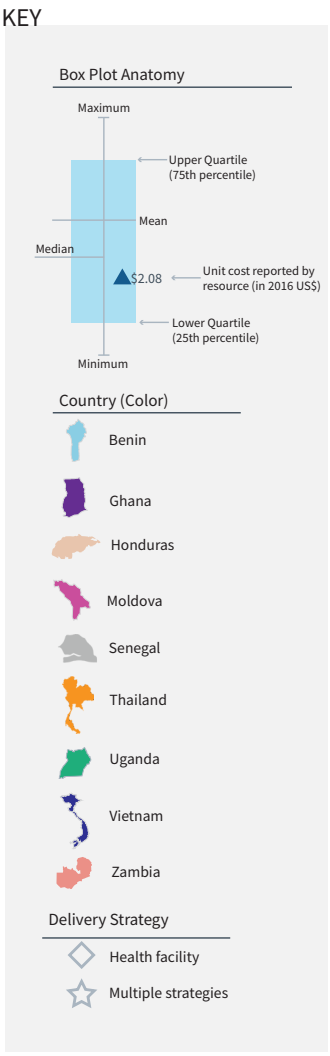
*The quality of each article/report was assessed using a checklist developed by the ICAN research team. The quality scores across all articles/reports ranged from 1.6 to 2.8, with an average (mean) score of 2.2.
**The ICAN research team considered paid HR, cold chain equipment and overheads, vehicles, transport, and fuel, and training and capacity building to be the major cost categories.
+ Includes both introduction/startup costs and recurrent/ongoing costs.

References:
[1]Levin, C. E., Van Minh, H., Odaga, J., Rout, S. S., Ngoc, D. N. T., Menezes, L., … LaMontagne, D. S. (2013). **Delivery cost of human papillomavirus vaccination of young adolescent girls in Peru, Uganda and Vietnam.** Bulletin of the World Health Organization, 91(8), 585–592. https://doi.org/10.2471/BLT.12.113837
[2]Quentin, W., Terris-Prestholt, F., Changalucha, J., Soteli, S., Edmunds, W. J., Hutubessy, R., … Watson-Jones, D. (2012). **Costs of delivering human papillomavirus vaccination to schoolgirls in Mwanza Region, Tanzania.** BMC Medicine, 10(November 2011). https://doi.org/10.1186/1741-7015-10-137

IMMUNIZATION DELIVERY UNIT COST RANGES 6-7

Full delivery cost estimates for delivering a schedule of vaccines, excluding vaccine cost (2016 US$)





UNIT COST (excluding vaccine cost)	Economic cost per dose	Economic cost per dose	Economic cost per fully immunized child (defined as children who have received DTP3)
DELIVERY STRATEGY	Health facility (routine delivery, not SIA)	Health facility & multiple strategies (i.e., two or more delivery strategies) (routine delivery, not SIA)	Health facility & multiple strategies (i.e., two or more delivery strategies) (routine delivery, not SIA)
OTHER COST DETAILS	Supply chain only costs, Includes both introduction/startup costs and recurrent/ ongoing costs	All costs (i.e., not supply chain only), Includes both introduction/ startup costs and recurrent/ongoing costs	All costs (i.e., not supply chain only), Includes both introduction/startup costs and recurrent/ongoing costs

ADDITIONAL DETAIL: FULL COST RANGE FOR DELIVERY OF A SCHEDULE OF VACCINES (EXCLUDING VACCINE COST) (2016 US$)

No.	Countries	Vaccines costed	Delivery strategy (platform)	Delivery sector	Delivery scale	Other notes for interpretation	Quality score of resources*	No. of cost categories (of 14)*	Type of unit cost+	Individual immunization delivery unit costs	Immunization delivery cost range (2016 US$)	Descriptive statistics (2016 US$)
6	Senegal, Thailand, Vietnam	Vaccination schedules containing 6-7 antigens	Health facility Routine delivery (not SIA)	Public sector	Full	Supply chain only costs	2.2-2.6	All supply chain only unit costs with 3-5 cost categories	Economic cost per dose	$0.22 (Vietnam, 6 antigens)[10] $0.26 (Thailand, 7 antigens)[8] $0.28 (Vietnam, 6 antigens)[10] $0.28 (Senegal, 6 antigens)[9] $0.33 (Thailand, 7 antigens)[8]	$0.22 - $0.33	**Mean: $0.28** 25th percentile: $0.26 **Median: $0.28** 75th percentile: $0.28
7	Benin, Ghana, Honduras, Moldova, Uganda, Zambia	Schedules of 4-8 antigens for under 1-year-olds	Health facility (fixed site) & multiple strategies (two or more delivery strate-gies) (Routine delivery, not SIA)	Public sector	National	Only facility-level costs are included (i.e., above-facility costs excluded) The unit costs are for different schedules, representing different numbers of antigens and doses	2.5 - 2.8	11-13 (all major cost categories included)	Economic cost per dose	$0.75 (Benin, health facility (hf))[1, 2] $1.67 (Uganda, hf)[3] $2.11 (Zambia, multiple strategies (mult strat))[2, 4] $3.18 (Ghana, mult strat)[2, 5] $5.57 (Honduras, mult strat)[6, 2] $9.45 (Moldova, hf)[7, 2]	$0.75 - $9.45	**Mean: $3.79** 25th percentile: $1.78 **Median: $2.64** 75th percentile: $4.97
8									Economic cost per fully immunized child (defined as children who have received DTP3)	$8.13 (Benin, hf)[1, 2] $16.23 (Uganda, hf)[3] $20.68 (Zambia, mult strat)[2, 4] $29.04 (Ghana, mult strat)[2, 5] $75.18 (Honduras, mult strat)[6, 2] $96.16 (Moldova, hf)[7, 2]	$8.13 - $96.16	**Mean: $40.90** 25th percentile: $17.34 **Median: $24.86** 75th percentile: $63.64

Note: This cost range combines unit cost data representing different schedules with different numbers of antigens and doses.
*The quality of each article/report was assessed using a checklist developed by the ICAN research team. The quality scores across all articles/reports ranged from 1.6 to 2.8, with an average (mean) score of 2.2.
**The ICAN research team considered paid HR, cold chain equipment and overheads, vehicles, transport, and fuel, and training and capacity building to be the major cost categories.
+ Includes both introduction/startup costs and recurrent/ongoing costs.

References:

[1]AMP. 2014. **Costing and financing analyses of routine immunization and new vaccine introduction in Benin Final Report.**

[2]Suharlim, C. and Menzies, N. 2018. Personal communication, based on EPI Costing and Financing Study - Phase 2 (EPIC2) Dataverse (Harvard T.H. Chan School of Public Health). https://dataverse.harvard.edu/dataverse/EPIC2

[3]Guthrie, T., Zikusooka, C., Kwesiga, B., Abewe, C., Lagony, S., Schutte, C., … Kinghorn, A. 2014. **Costing and Financing Analyses of Routine Immunization in Uganda.** Rivonia, South Africa: Health Development for Africa.

[4]Schütte, C., Chansa, C., Marinda, E., Guthrie, T. A., Banda, S., Nombewu, Z., … Kinghorn, A. **2015. Cost analysis of routine immunisation in Zambia.** Vaccine 33(S1): A47–A52. https://doi.org/10.1016/j.vaccine.2014.12.040

[5]Le Gargasson, J. B., Nyonator, F. K., Adibo, M., Gessner, B. D., & Colombini, A. 2015. **Costs of routine immunization and the introduction of new and underutilized vaccines in Ghana.** Vaccine 33(S1):A40–A46.

[6]Pan American Health Organization. 2014. **Comprehensive costing and financial flows analysis of the national immunization program in Honduras**, 2011.

[7]Goguadze, K., Chikovani, I., Gaberi, C., Maceira, D., Uchaneishvili, M., Chkhaidze, N., and Gotsadze, G. 2015. **Costs of routine immunization services in Moldova: Findings of a facility-based costing study**. Vaccine 33(S1):A60–A65. https://doi.org/10.1016/j.vaccine.2014.12.034

[8]PATH, World Health Organisation, Health Systems Research Institute, & Mahidol University. (2011). **An Assessment of Vaccine Supply Chain and Logistics Systems in Thailand.** Path, (September), 1–58.

[9]PATH. (2013). **Optimize: Senegal Report.**

[10]Mvundura, M., Kien, V. D., Nga, N. T., Robertson, J., Van Cuong, N., Tung, H. T., … Levin, C. (2014). **How much does it cost to get a dose of vaccine to the service delivery location: Empirical evidence from Vietnam's Expanded Program on Immunization.** Vaccine, 32(7), 834–838. https://doi.org/10.1016/j.vaccine.2013.12.029

VII. CONCLUSIONS

This systematic review has responded to the need for compiled, analyzed evidence on IDCs in LMICs. It goes beyond past attempts that looked only at a subset of vaccines, a subset of economic evaluations, or costs of new vaccine introduction only, considering over 15,000 resources on the topic. Ultimately, it draws from 61 resources on IDC data without focusing solely on a particular vaccine, delivery strategy, type of cost analysis, or setting. This produced a dataset of 410 immunization delivery unit costs (i.e., cost per capita, per dose, per full immunization of a vaccine, per fully immunized child, or per person in the target population), now available in the Immunization Delivery Cost Catalogue (IDCC) **immunizationeconomics.org/ican-idcc**, all presented in 2016 US dollars for easy referencing and use.

This summary report has described the evidence in terms of its spread/scope, methods/reporting, and quality. It has also presented an analysis of cost ranges for vaccine delivery through a variety of strategies and in a variety of contexts.

In terms of the spread/scope of the evidence, the analysis has shown that an increasing number of resources on IDCs have been being published in recent years, thanks to several large immunization costing projects.

Immunization delivery unit cost evidence is available for 33 countries in every region and income group, with sub-Saharan Africa and low-income countries particularly well represented. Other than PCV, HPV, and Rotavirus vaccines, which have been increasingly rolled out in recent years, there are limited data available about other single vaccines. Data are also limited on the cost of schedules of vaccines, where there is great variety in antigens, vaccines, and number of required doses. Most of the immunization delivery unit costs pertain to public health facility delivery, reflecting the predominant delivery of vaccines at fixed sites. Despite widespread use of outreach/mobile strategies and campaigns, there is scant evidence on the costs of delivery via these strategies.

Unit costs are available from only 33 countries, primarily low income, and the overwhelming majority are for health facility-based delivery, despite the widespread use of outreach/mobile strategies and vaccination campaigns. Our review has also shown that we know relatively little about the costs of delivering single vaccines other than PCV and HPV, or the cost of delivering schedules of vaccines due to their diversity in composition and their number of antigens.

Data are available for 33 countries in every region and income group, with Sub-Saharan Africa and low-income countries particularly well represented.

In low-income countries, the incremental cost per dose (excluding vaccine cost) to deliver single, newly introduced vaccines at health facilities ranged from $0.48 to $1.38 considering only economic costs. This contrasts with a range of $0.16 to $2.54 considering economic, financial and fiscal costs. The incremental cost for full immunization (i.e., 3 doses) of a vaccine ranged from $1.45 to $4.20 considering only economic costs.

Evidence indicates introducing HPV at schools on a pilot/project basis results in an incremental cost between $1.95 and $4.29 (the lower end of the range represents financial costs, whereas the higher end of the range corresponds with economic costs). Although there are limited immunization delivery unit costs for delivery via other delivery strategies, our analysis suggests that other strategies are more expensive than facility-based delivery.

Looking only at supply chain-related costs, the full, economic cost per dose of delivering vaccination schedules containing 6 to 7 antigens (excluding vaccine cost) ranged from $0.22 to $0.33. Looking at all costs (i.e., not supply chain only), the full, economic cost per dose of delivering schedules of 4 to 8 vaccines to under one-year-olds ranged from $0.75 to $9.45. This equates to a cost per fully immunized child (defined by the study authors as children who have received DTP3) ranging from $8.13 to $96.16.

Methods and reporting on immunization delivery unit cost data need to be improved to allow users of the data to better understand how the study was conducted and the type of costs and cost categories included. Indeed, some of the variation shown in the IDCC may be more reflective of differences in methods and/or reporting rather than of actual cost differences.

These findings should be useful for anyone interested in understanding the evidence base on IDCs, gaining inspiration for additional research in this area, or supporting countries in considering their IDC needs and comparing their costs to peers. This may include national and sub-national planners and policymakers, researchers, and international partners supporting country immunization and health system policy, planning, and financing.

There are additional tools and products, including a detailed methodology note and user guides, accessible at **http://immunizationeconomics.org/ican-idcc** to help with interpretation of the systematic review and to dig deeper into the variation in and drivers of IDCs across country contexts and delivery strategies.

Further, the systematic review and analytics will be refreshed again in 2019 under the Immunization Costing Action Network (ICAN) and supported by the Bill & Melinda Gates Foundation. Our aim is to capture newly released resources in the refresh, and to update the findings based on insights from immunization economics experts and feedback from users on the methodology and accessibility of the content.

[15] Estimates may not be comparable because they use different costing methodologies, include different cost categories, represent different types of delivery (nationwide rollout versus pilot/project scale), and so on.

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Brenzel, L. 2013. *Working Paper: Common Approach for the Costing and Financing Analyses of Routine Immunization and New Vaccine Introduction Costs (NUVI)*. Seattle: Bill & Melinda Gates Foundation.

Castañeda-Orjuela et al. 2013. Using standardized tools to improve immunization costing data for program planning: The cost of the Colombian Expanded Program on Immunization. *Vaccine* 31 Suppl.3:72–79

De la Hoz-Restrepo, F. et al. 2013. Systematic review of incremental non-vaccine cost estimates used in cost-effectiveness analysis on the introduction of rotavirus and pneumococcal vaccines. *Vaccine* 315 Suppl. 3:C80-C87.

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Goguadze, K., I. Chikovani, C. Gaberi, D. Maceira, M. Uchaneishvili, N. Chkhaidze, and G. Gotsadze. 2015. Costs of routine immunization services in Moldova: Findings of a facility-based costing study. *Vaccine* 33(S1):A60–A65. **https://doi.org/10.1016/j.vaccine.2014.12.034.**

Gotsadze, G., K. Goguadze, I. Chikovani, and D. Maceira. 2014. *Analyses of Costs and Financing of the Routine Immunization Program and New Vaccine Introduction in the Republic of Moldova Study Report*. Tbilisi, Georgia: Curatio Foundation.

Guthrie, T. et al. 2014. *Costing and Financing Analyses of Routine Immunization in Uganda*. Rivonia, South Africa: Heath & Development Africa.

ICAN / Immunization Costing Action Network. 2018. *Immunization Delivery Costs in Low- and Middle-income Countries A methodology note for the systematic review, cost catalogue, and analytics.* Accessed May 23, 2018. **Immunizationeconomics.org/icanidccmethodologynote.**

Le Gargasson, J. et al. 2015. Costs of routine immunization and the introduction of new and underutilized vaccines in Ghana. *Vaccine* 33(S1):A40–A46.

Levin, C. et al. 2015. *Working paper for the convening on immunization delivery costs. Presentation at a meeting on immunization delivery costs*. October 14-15. Seattle, WA.

Mogasale, V. et al. 2016. Oral Cholera Vaccination Delivery Cost in Low- and Middle-Income Countries: An Analysis Based on Systematic Review. *PLoS Neglected Tropical Diseases* 10(12):e0005124.

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Ngabo, F. et al. 2015. A cost comparison of introducing and delivering pneumococcal, rotavirus and human papillomavirus vaccines in Rwanda. *Vaccine* 33(51):7357–7363.

Ozawa et al. 2012. Cost-effectiveness and economic benefits of vaccines in low- and middle-income countries: A systematic review. *Vaccine* 31:96-108.

Pan American Health Organization (PAHO). 2014. *Comprehensive costing and financial flows analysis of the national immunization program in Honduras, 2011*. Washington: PAHO.

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PATH. n.d. *HPV Vaccines: Evidence for Impact*. Accessed May 28, 2018. **http://www.path.org/files/1867_HPV_Vaccines_intro.pdf**

Schütte, C. et al. 2015. Cost analysis of routine immunisation in Zambia. *Vaccine* 33(S1): A47–A52. **https://www.sciencedirect.com/science/article/pii/S0264410X14016934**

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ANNEXES

ANNEX 1. REFERENCES OF EXTRACTED ARTICLES/REPORTS

Reference	Unit Costs	Countries	Vaccines Costed*
Al-lela, O. Q. B., Bahari, M. B., Al-abbassi, M. G., Salih, M. R. M., & Basher, A. Y. (2012). Estimation of immunization providers' activities cost, medication cost, and immunization dose errors cost in Iraq. *Vaccine*, 30(26), 3862–3866. **https://doi.org/10.1016/j.vaccine.2012.04.014**	2	Iraq	BCG, Measles, MMR, HepB, DTP, OPV
AMP. (2014). Costing and financing analyses of routine immunization and new vaccine introduction in Benin Final Report.**	28	Benin	BCG, Measles, DTP-HepB-Hib, OPV, PCV13, YF
Ayieko, P., Griffiths, U. K., Ndiritu, M., Moisi, J., Mugoya, I. K., Kamau, T., … Scott, J. A. G. (2013). Assessment of Health Benefits and Cost-Effectiveness of 10-Valent and 13-Valent Pneumococcal Conjugate Vaccination in Kenyan Children. *PLoS ONE*, 8(6), 1–10. **https://doi.org/10.1371/journal.pone.0067324**	4	Kenya	PCV10, PCV13
Bem, J. and Stewart, E. "Vaccine Costing Analysis Preliminary Results." Presentation at the Pharmaceutical Fund and Supply Agency, Addis Ababa, Ethiopia, September 2015.	7	Ethiopia	OPV, Rotavirus, (2 doses), TT, PCV10, BCG, Measles, DTP
Bishai, D., Johns, B., Lefevre, A., & Nair, D. (2010). Cost effectiveness of measles eradication Final Report. Retrieved from **http://www.who.int/immunization/sage/1_Bishai_Economic_analysis.pdf**	2	Uganda	Measles
Brown, S. T., Schreiber, B., Cakouros, B. E., Wateska, A. R., Dicko, H. M., Connor, D. L., … Lee, B. Y. (2014). The benefits of redesigning Benin's vaccine supply chain. *Vaccine*, 32(32), 4097–4103. **https://doi.org/10.1016/j.vaccine.2014.04.090****	4	Benin	BCG, Measles, TT, DTP-HepB-Hib, OPV, Rotavirus (2 doses), PCV13, YF
Castañeda-Orjuela, C., Romero, M., Arce, P., Resch, S., Janusz, C. B., Toscano, C. M., & De la Hoz-Restrepo, F. (2013). Using standardized tools to improve immunization costing data for program planning: The cost of the Colombian Expanded Program on Immunization. *Vaccine*, 31(SUPPL.3), 72–79. **https://doi.org/10.1016/j.vaccine.2013.05.038**†	4	Columbia	BCG, MR, MMR, HepB, DTP, DT, Td, DTP-HepB-Hib, OPV, Rotavirus (2 doses), PCV7, YF, Influenza
Cavailler, P., Lucas, M., Perroud, V., McChesney, M., Ampuero, S., Guérin, P. J., … Chaignat, C. L. (2006). Feasibility of a mass vaccination campaign using a two-dose oral cholera vaccine in an urban cholera-endemic setting in Mozambique. *Vaccine*, 24(22), 4890–4895. **https://doi.org/10.1016/j.vaccine.2005.10.006**	1	Mozambique	OCV

Chatterjee, S., Pant, M., Haldar, P., Aggarwal, M. K., & Laxminarayan, R. (2016). Current costs & projected financial needs of India's universal immunization programme. *Indian Journal of Medical Research,* 143(JUNE), 801–808. **https://doi.org/10.4103/0971-5916.192073**	2	India	BCG, Measles, HepB, DTP, TT, OPV, JE
Colombini, A., Badolo, O., Gessner, B. D., Jaillard, P., Seini, E., & Da Silva, A. (2011). Costs and impact of meningitis epidemics for the public health system in Burkina Faso. *Vaccine*, 29(33), 5474–5480. **https://doi.org/10.1016/j.vaccine.2011.05.058**	2	Burkina Faso	Meningococcal
Dorji, K., Phuntsho, S., Pempa, Kumluang, S., Khuntha, S., Kulpeng, W., … Teerawattananon, Y. (2018). Towards the introduction of pneumococcal conjugate vaccines in Bhutan: A cost-utility analysis to determine the optimal policy option. ***Vaccine,*** 36(13), 1757-65. **https://doi.org/10.1016/j.vaccine.2018.02.048**	2	Bhutan	PCV10, PCV13
Douba, A., Dagnan, S. N., Zengbe-Acray, P., Aka, J., & Lépri-Aka N. (2006). Perception du Programme élargi de vaccination (PEV) dans le district sanitaire de Bouna (Nord-Est de la Côte d 'Ivoire). *Sante Publique*, 23(2), 113-121.	5	Côte d 'Ivoire	BCG, DTP-HepB, OPV
Ebong, C. E., & Levy, P. (2011). Impact of the introduction of new vaccines and vaccine wastage rate on the cost-effectiveness of routine EPI: Lessons from a descriptive study in a Cameroonian health district. *Cost Effectiveness and Resource Allocation*, 9, 1–8. https://doi.org/10.1186/1478-7547-9-9	3	Cameroon	BCG, Measles, DTP-HepB-Hib, OPV, YF
Goguadze, K., Chikovani, I., Gaberi, C., Maceira, D., Uchaneishvili, M., Chkhaidze, N., & Gotsadze, G. (2015). Costs of routine immunization services in Moldova: Findings of a facility-based costing study. *Vaccine*, 33(S1), A60–A65. **https://doi.org/10.1016/j.vaccine.2014.12.034** **	4	Moldova	BCG, MMR, HepB, DTP-HepB-Hib, OPV
Gotsadze, G., Goguadze, K., Chikovani, I., & Maceira, D. (2014). Analyses of Costs and Financing of the Routine Immunization Program and New Vaccine Introduction in the Republic of Moldova Study Report. **	34	Moldova	BCG, MMR, HepB, DTP, DT, Td, DTwP-Hib, DTP-HepB-Hib, OPV, Rotavirus (2 doses)
Griffiths, U. K., Hutton, G., & Das Dores Pascoal, E. (2005). The cost-effectiveness of introducing hepatitis B vaccine into infant immunization services in Mozambique. *Health Policy and Planning*, 20(1), 50–59. **https://doi.org/10.1093/heapol/czi006**	3	Mozambique	BCG, Measles, TT, OPV, HepB, DTP-HepB
Griffiths, U. K., Korczak, V. S., Ayalew, D., & Yigzaw, A. (2009). Incremental system costs of introducing combined DTwP-hepatitis B-Hib vaccine into national immunization services in Ethiopia. *Vaccine*, 27(9), 1426–1432. **https://doi.org/10.1016/j.vaccine.2008.12.037**	2	Ethiopia	DTwP-HepB-Hib
Griffiths, U. K., Bozzani, F. M., Chansa, C., Kinghorn, A., Kalesha-Masumbu, P., Rudd, C., … Schutte, C. (2016). Costs of introducing pneumococcal, rotavirus and a second dose of measles vaccine into the Zambian immunisation programme: Are expansions sustainable? *Vaccine*, 34(35), 4213–4220. **https://doi.org/10.1016/j.vaccine.2016.06.050****	15	Zambia	Measles, Rotavirus (2 doses), PCV10

Griffiths, U. K., Santos, A. C., Nundy, N., Jacoby, E., & Matthias, D. (2011). Incremental costs of introducing jet injection technology for delivery of routine childhood vaccinations: Comparative analysis from Brazil, India, and South Africa. *Vaccine*, 29(5), 969–975. **https://doi.org/10.1016/j.vaccine.2010.11.038**	15	Brazil, India, South Africa	BCG, MMR, HepB, DTwP-Hib, YF, Measles, DT, TT, DTaP-Hib-IPV, PCV7, DTwP
Guthrie, T., Zikusooka, C., Kwesiga, B., Abewe, C., Lagony, S., Schutte, C., … Kinghorn, A. (2014). Costing and Financing Analyses of Routine Immunization in Uganda. Retrieved from **http://bit.ly/2CtYVKU**	72	Uganda	BCG, Measles, TT, DTP-HepB-Hib, OPV, PCV10
Haidari, L. A., Wahl, B., Brown, S. T., Privor-Dumm, L., Wallman-Stokes, C., Gorham, K., … Lee, B. Y. (2015). One size does not fit all: The impact of primary vaccine container size on vaccine distribution and delivery. *Vaccine*, 33(28), 3242–3247. **https://doi.org/10.1016/j.vaccine.2015.04.018** ***	2	Benin	BCG, Measles, TT, DTP-HepB-Hib, OPV, Rotavirus (2 doses), PCV13, YF
Haidari, L. A., Brown, S. T., Ferguson, M., Bancroft, E., Spiker, M., Wilcox, A., … Lee, B. Y. (2016). The economic and operational value of using drones to transport vaccines. *Vaccine*, 34(34), 4062–4067. **https://doi.org/10.1016/j.vaccine.2016.06.022****	1	Mozambique	BCG, Measles, TT, DTP-HepB-Hib, OPV, PCV10
Haque, M., Waheed, M., & et al. (2016). The Pakistan Expanded Program on Immunization and the National Immunization Support Project. Retrieved from **http://documents.worldbank.org/curated/en/264971484109785001/pdf/111815-WP-PAKImmunizationEA-PUBLIC.pdf**	1	Pakistan	BCG, Measles, DTP, OPV
Huang, X.X., Guillermet, E., Le Gargasson, J.B., Alfa, D.A., Gboja, R., Sossou, A.J., Jaillard, P. (2017). Costing analysis and anthropological assessment of the vaccine supply chain system redesign in the Comé District (Benin). *Vaccine*, 35(16), 2183-8. https://doi.org/10.1016/j.vaccine.2016.12.075	2	Benin	BCG, Measles, TT, DTwP-HepB-Hib, PCV13, YF, OCV
Hutubessy, R., Levin, A., Wang, S., Morgan, W., Ally, M., John, T., & Broutet, N. (2012). A case study using the United Republic of Tanzania: Costing nationwide HPV vaccine delivery using the WHO Cervical Cancer Prevention and Control Costing Tool. *BMC Medicine*, 10, 1–10. **https://doi.org/10.1186/1741-7015-10-136**††	14	Tanzania	HPV
Janusz, C. B., Castañeda-Orjuela, C., Molina Aguilera, I. B., Felix Garcia, A. G., Mendoza, L., Díaz, I. Y., & Resch, S. C. (2015). Examining the cost of delivering routine immunization in Honduras. *Vaccine,* 33(S1), A53–A59. **https://doi.org/10.1016/j.vaccine.2015.01.016****	2	Honduras	BCG, MMR, HepB, Td, DTP-HepB-Hib, OPV, IPV, Rotavirus (2 doses), PCV13, YF, Influenza
Kar, S. K., Sah, B., Patnaik, B., Kim, Y. H., Kerketta, A. S., Shin, S., … Wierzba, T. F. (2014). Mass Vaccination with a New, Less Expensive Oral Cholera Vaccine Using Public Health Infrastructure in India: The Odisha Model. *PLoS Neglected Tropical Diseases*, 8(2). **https://doi.org/10.1371/journal.pntd.0002629**	3	India	OCV

Kaucley, L., & Levy, P. (2015). Cost-effectiveness analysis of routine immunization and supplementary immunization activity for measles in a health district of Benin. *Cost Effectiveness and Resource Allocation*, 13(1), 14. **https://doi.org/10.1186/s12962-015-0039-7**	6	Benin	Measles
Khan, I. A., Saha, A., Chowdhury, F., Khan, A. I., Uddin, M. J., Begum, Y. A., … Qadri, F. (2013). Coverage and cost of a large oral cholera vaccination program in a high-risk cholera endemic urban population in Dhaka, Bangladesh. *Vaccine*, 31(51), 6058–6064. **https://doi.org/10.1016/j.vaccine.2013.10.021** †††	3	Bangladesh	OCV
Le Gargasson, J. B., Nyonator, F. K., Adibo, M., Gessner, B. D., & Colombini, A. (2015). Costs of routine immunization and the introduction of new and underutilized vaccines in Ghana. *Vaccine,* 33(S1), A40–A46. **https://doi.org/10.1016/j.vaccine.2014.12.081****	4	Ghana	BCG, Measles, TT, DTP-HepB-Hib, OPV, YF, Rotavirus (2 doses), PCV13
Levin, C. E., Nelson, C. M., Widjaya, A., Moniaga, V., & Anwar, C. (2005). Costs of hepatitis B vaccine in a prefilled syringe in Indonesia. *Bulletin of the World Health Organization*, 83(3), 456–461. **https://www.sciencedirect.com/science/article/pii/S0264410X14016934**	2	Indonesia	HepB
Levin, C. E., Van Minh, H., Odaga, J., Rout, S. S., Ngoc, D. N. T., Menezes, L., … LaMontagne, D. S. (2013). Delivery cost of human papillomavirus vaccination of young adolescent girls in Peru, Uganda and Viet Nam. Bulletin of the *World Health Organization,* 91(8), 585–592. **https://doi.org/10.2471/BLT.12.113837**	10	Peru, Uganda, Vietnam	HPV
Levin, A., Wang, S. A., Levin, C., Tsu, V., & Hutubessy, R. (2014). Costs of introducing and delivering HPV vaccines in low and lower middle income countries: Inputs for GAVI policy on introduction grant support to countries. *PLoS ONE*, 9(6). **https://doi.org/10.1371/journal.pone.0101114**	30	Bhutan, India, Peru, Tanzania, Uganda, Vietnam	HPV
Lydon, P., Zipursky, S., Tevi-Benissan, C., Djingarey, M.H., Gbedonou, P., Youssouf, B.O., Zaffran, M. (2014). Economic benefits of keeping vaccines at ambient temperature during mass vaccination: the case of meningitis A vaccine in Chad. *Bulletin of the World Health Organization*, 92, 86-92. **http://dx.doi.org/10.2471/BLT.13.123471**	2	Chad	Meningococcal
Mascareñas, A., Salinas, J., Tasset-Tisseau, A., Mascareñas, C., & Khan, M. M. (2005). Polio immunization policy in Mexico: Economic assessment of current practice and future alternatives. *Public Health*, 119(6), 542–549. **https://doi.org/10.1016/j.puhe.2004.08.020**	2	Mexico	OPV
Minh, V. H., Nguyen, T. B. Y., Bao, G. K., Lan, H. D., Thuy, H. N., & Wright, P. (2008). Cost of providing the expanded programme on immunization: Findings from a facility-based study in Viet Nam, 2005. *Bulletin of the World Health Organization*, 86(6), 429–434. **https://doi.org/10.2471/BLT.07.045161**	1	Vietnam	HPV

Minh, V. H., Nguyen, T. B. Y., Bao, G. K., Lan, H. D., Thuy, H. N., & Wright, P. (2008). Cost of providing the expanded programme on immunization: Findings from a facility-based study in Viet Nam, 2005. Bulletin of the World Health Organization, 86(6), 429–434. **https://doi.org/10.2471/BLT.07.045161**	6	Vietnam	BCG, Measles, HepB, DTP, TT, OPV, JE
Moodley, I., Tathiah, N., & Sartorius, B. (2016). The costs of delivering human papillomavirus vaccination to Grade 4 learners in KwaZulu-Natal, South Africa. *South African Medical Journal = Suid-Afrikaanse Tydskrif Vir Geneeskunde*, 106(5), 60. **https://dx.doi.org/10.7196/SAMJ.2016.v106i5.9988**	1	South Africa	HPV
Mvundura, M., Kien, V. D., Nga, N. T., Robertson, J., Van Cuong, N., Tung, H. T., … Levin, C. (2014). How much does it cost to get a dose of vaccine to the service delivery location: Empirical evidence from Vietnam's Expanded Program on Immunization. *Vaccine*, 32(7), 834–838. **https://doi.org/10.1016/j.vaccine.2013.12.029**‡	4	Vietnam	BCG, Measles, HepB, DTwP, TT, OPV, DTP-HepB-Hib
Mvundura, M., Lorenson, K., Chweya, A., Kigadye, R., Bartholomew, K., Makame, M., … Kristensen, D. (2015). Estimating the costs of the vaccine supply chain and service delivery for selected districts in Kenya and Tanzania. *Vaccine*, 33(23), 2697–2703. **https://doi.org/10.1016/j.vaccine.2015.03.084**	2	Kenya, Tanzania	BCG, Measles, Td, DTP-HepB-Hib, OPV, PCV10, YF
Mvundura, M., Lydon, P., Gueye, A., Diaw, I.K., Landoh, D.E., Toi, B., … Kristensen, D. (2017). An economic evaluation of the controlled temperature chain approach for vaccine logistics: evidence from a study conducted during a meningitis A vaccine campaign in Togo. *The Pan African Medical Journal*, 27(Supp 3), 27. **doi:10.11604/pamj.supp.2017.27.3.12087**	2	Togo	Meningococcal
Ngabo, F., Levin, A., Wang, S. A., Gatera, M., Rugambwa, C., Kayonga, C., … Hutubessy, R. (2015). A cost comparison of introducing and delivering pneumococcal, rotavirus and human papillomavirus vaccines in Rwanda. *Vaccine*, 33(51), 7357–7363. **https://doi.org/10.1016/j.vaccine.2015.10.022**	24	Rwanda	PCV7, Rotavirus (3 doses), HPV
Pan American Health Organization. (2014). Comprehensive costing and financial flows analysis of the national immunization program in Honduras, 2011.**	1	Honduras	BCG, MMR, HepB, DTP, Td, DTP-HepB-Hib, OPV, IPV, Rotavirus (2 doses), PCV13, YF, Influenza
PATH. (2013). Optimize: Senegal Report. ‡	1	Senegal	BCG, Measles, TT, DTwP-HepB-Hib, OPV, YF
PATH, World Health Organization, Health Systems Research Institute, & Mahidol University. (2011). An Assessment of Vaccine Supply Chain and Logistics Systems in Thailand. PATH (September), 1–58. ‡	2	Thailand	BCG, Measles, MMR, HepB, DTP, OPV, JE

Quentin, W., Terris-Prestholt, F., Changalucha, J., Soteli, S., Edmunds, W. J., Hutubessy, R., … Watson-Jones, D. (2012). Costs of delivering human papillomavirus vaccination to schoolgirls in Mwanza Region, Tanzania. *BMC Medicine*, 10(November 2011). **https://doi.org/10.1186/1741-7015-10-137**	5	Tanzania	HPV
Riewpaiboon, A., Sooksriwong, C., Chaiyakunapruk, N., Tharmaphornpilas, P., Techathawat, S., Rookkapan, K., … Suraratdecha, C. (2015). Optimizing national immunization program supply chain management in Thailand: an economic analysis. *Public Health*, 129(7), 899-906. 1016/j.puhe.2015.04.016	4	Thailand	BCG, Measles, MMR, HepB, DTP, DT, DTP-Hib, OPV, JE
Routh, J.A., Sreenivasan, N., Adhikari, B.B., Andrecy, L.L., Bernateau, M., Abimbola, T., … Mintz, E.D. (2017). Cost evaluation of a government-conducted oral cholera vaccination campaign - Haiti, 2013. T*he American Society of Tropical Medicine and Hygiene*, 97(4), 37-42. doi:10.4269/ajtmh.16-1023	5	Haiti	OCV
Ruhago, G. M., Ngalesoni, F. N., Robberstad, B., & Norheim, O. F. (2015). Cost-effectiveness of live oral attenuated human rotavirus vaccine in Tanzania. *Cost Effectiveness and Resource Allocation*, 13(1), 1–12. **https://doi.org/10.1186/s12962-015-0033-0**	3	Tanzania	Rotavirus (2 doses)
Sarker, A. R., Islam, Z., Khan, I. A., Saha, A., Chowdhury, F., Khan, A. I., … Khan, J. A. M. (2015). Estimating the cost of cholera-vaccine delivery from the societal point of view: A case of introduction of cholera vaccine in Bangladesh. *Vaccine*, 33(38), 4916–4921. **https://doi.org/10.1016/j.vaccine.2015.07.042** †††	3	Bangladesh	OCV
Schaetti, C., Weiss, M. G., Ali, S. M., Chaignat, C. L., Khatib, A. M., Reyburn, R., … Hutubessy, R. (2012). Costs of Illness Due to Cholera, Costs of Immunization and Cost-Effectiveness of an Oral Cholera Mass Vaccination Campaign in Zanzibar. P*LoS Neglected Tropical Diseases*, 6(10). **https://doi.org/10.1371/journal.pntd.0001844**	2	Tanzania	OCV
Schütte, C., Chansa, C., Marinda, E., Guthrie, T. A., Banda, S., Nombewu, Z., … Kinghorn, A. (2015). Cost analysis of routine immunisation in Zambia. *Vaccine,* 33(S1), A47–A52. **https://doi.org/10.1016/j.vaccine.2014.12.040****	4	Zambia	BCG, Measles, DTP-HepB-Hib, OPV
Suharlim, C. and Menzies, N. (2018) Personal communication, based on EPI Costing and Financing Study - Phase 2 (EPIC2) Dataverse (Harvard T.H. Chan School of Public Health). **https://dataverse.harvard.edu/dataverse/EPIC2**	16	Benin, Ghana, Honduras, Moldova, Uganda, Zambia	BCG, Measles, MMR, HepB, DTP, Td, DTP-Hib, DTP-HepB-Hib, OPV, IPV, Rotavirus (2 doses), PCV13, YF

Sume, G. E., Fouda, A. A. B., Kobela, M., Nguelé, S., Emah, I., & Atem, P. (2013). A locally initiated and executed measles outbreak response immunization campaign in the nylon health district, Douala Cameroon 2011. *BMC Research Notes*, 6(1). **https://doi.org/10.1186/1756-0500-6-100**	1	Cameroon	Measles
Teshome, S., Desai, S., Kim, J.H., Belay, D., & Mogasale, V. (2018). Feasibility and costs of a targeted cholera vaccination campaign in Ethiopia. *Human Vaccines & Immunotherapeutics*. **https://doi.org/10.1080/21645515.2018.1460295**	5	Ethiopia	OCV
Usuf, E., Mackenzie, G., Lowe-Jallow, Y., Boye, B., Atherly, D., Suraratdecha, C., & Griffiths, U. K. (2014). Costs of vaccine delivery in the Gambia before and after, pentavalent and pneumococcal conjugate vaccine introductions. *Vaccine*, 32(17), 1975–1981. **https://doi.org/10.1016/j.vaccine.2014.01.045**	4	The Gambia	DTP-HepB-Hib, HepB, TT, OPV, YF, PCV7
VillageReach. (2009). Comparison of Costs Incurred in Dedicated and Diffused Vaccine Logistics Systems, (October), 1–42. ‡‡‡	6	Mozambique	BCG, Measles, TT, DTP-HepB, OPV
Yin, Z., Beeler Asay, G. R., Zhang, L., Li, Y., Zuo, S., Hutin, Y. J., … Jiang, F. (2012). An economic evaluation of the use of Japanese encephalitis vaccine in the expanded program of immunization of Guizhou province, China. *Vaccine*, 30(37), 5569–5577. **https://doi.org/10.1016/j.vaccine.2012.05.068**	2	China	JE
Yu, W., Lu, M., Wang, H., Rodewald, L., Ji, S., Ma, C., … Liu, Y. (2018). Routine immunization services costs and financing in China, 2015. *Vaccine*, 36(21), 3041-7. 10.1016/j.vaccine.2018.04.008	4	China	BCG, MR, MMR, HepB, DTP, DT, OPV, IPV, JE, Meningococcal
Zengbe-Acray, P., Douba, A., Traore, Y., Dagnan, S., Attoh-Toure, H., & Ekra, D. (2009). Coûts de la riposte vaccinale contre la fièvre jaune à abidjan, 2001. *Sante Publique*, 21(4), 383–391.	2	Côte d 'Ivoire	YF

*DT = Diphtheria and tetanus toxoids, pediatric formulation; DTaP = Diphtheria and tetanus toxoids and acellular pertussis vaccine, pediatric formulation; DTP = Diphtheria and tetanus toxoids and whole-cell pertussis vaccine, pediatric formulation; HepB = Hepatitis B Vaccine; Hib = Haemophilus influenzae type b; HPV = Human Papillomavirus; IPV = Inactivated Poliovirus Vaccine; JE = Japanese Encephalitis; MCV = Measles antigen-containing vaccines; MMR = Measles, Mumps & Rubella Vaccine; MR = Measles-rubella Vaccine; OPV = Oral Polio Vaccine; PCV = Pneumococcal Conjugate Vaccine; PCV7 = Pneumococcal Conjugate Vaccine (7-valent); PCV10 = Pneumococcal Conjugate Vaccine (10-valent); PCV13 = Pneumococcal Conjugate Vaccine (13-valent); Tetanus & diphtheria Vaccine, adult/adolescent formulation; TT = Tetanus Toxoid; YF = Yellow Fever

** EPI Costing and Financing Project (EPIC)

*** Highly Extensible Resource for Modeling Event-driven Supply chains (HERMES) Framework

† ProVac Initiative

†† Cervical Cancer Prevention and Control Costing (C4P) tool demonstration for planning and costing nationwide HPV vaccination programs

††† Introduction of Cholera Vaccine in Bangladesh (ICVB)

‡ Project Optimize

‡‡ HPV Vaccines: Evidence for Impact project

‡‡‡ Project to Support PAV (EPI) to strengthen the management, reliability and quality of the health system in Mozambique

ANNEX 2. DEFINITIONS

Term	Definition
Cost category	Groupings of costs; also known as cost item, line item, etc. We used the following cost categories: Paid human resources, Volunteer human resources (economic costs only), Per diem and travel allowances, Cold chain equipment and their overheads (installation, energy, maintenance, repairs), Vehicles, transport and fuel, Program management, Training and capacity building, Social mobilization and advocacy, AEFI and disease surveillance, Buildings, utilities, other overheads and/or shared costs, Vaccines, Vaccine supplies, Waste management, Other supplies and recurrent costs, Other category costs.
Delivery cost	Frequently referred to at country level as "operational costs". The costs associated with delivering immunizations to target populations, exclusive of vaccine costs. Delivery costs may include any or all of the following items: paid and volunteer human resources and associated per diem and travel allowances, cold chain equipment and overheads, vehicles, transport and fuel, program management, training and capacity building, social mobilization and advocacy, adverse event following immunization (AEFI) and disease surveillance, buildings, utilities, other overheads and shared costs, vaccine supplies, waste management, other supplies and recurrent costs and other costs. We refer to these inputs as "cost categories"; some resources refer to them as line items and/or activities.
Delivery strategy	How and where vaccines are delivered, such as through health facilities, outreach/mobile clinics (off-site delivery, generally to patients located more than a certain distance from a health facility; this delivery strategy may be called mobile in some countries, or outreach in others), schools, child health days/weeks or national immunization days/weeks, campaigns and multiple strategies (two or more of the aforementioned strategies).
Discount rate	The rate at which future costs are considered compared to those that occur in the present.
Economic cost	Financial outlays plus opportunity costs such as health worker time and any donated items such as vaccines.
Financial cost	Financial outlays, usually with straight-line depreciation of capital items.
Fiscal cost	Financial outlays, usually without depreciation of capital items.
Full/total	The sum of all costs associated with vaccination delivery.
Full immunization of a vaccine	All required doses of a specific vaccine (e.g., three doses of HPV).

Term	Definition
Fully immunized child (FIC)	Generally refers to provision of a certain number of doses of a specific vaccine(s) to a specific group and at a clear point in time (e.g., infants who received all vaccines in the schedule before reaching one year of age), as opposed to a standard global definition, for example, of DPT3.
Highest level of costs included	The level (national, provincial/regional, district, facility, etc.) to which operational costs have been included (excludes vaccines).
Routine	Defined by WHO as "sustainable, reliable and timely interaction between the vaccine, those who deliver it and those who receive it to ensure every person is fully immunized against vaccine-preventable diseases."
Shared costs	Delivery costs that are also used for non-immunization, for example vehicles that are used for outreach but also used for HIV.
Standardized findings	Refers to the data extracted as part of the systematic review, presented in a standard format in the International Delivery Cost Catalogue (IDCC) with all costs brought to 2016 USD.
Supplementary immunization activity (SIA)	Strategy for delivering vaccination to children otherwise missed by routine immunization, or in response to a specific event, such as a disease outbreak.
Type of cost	Either financial, fiscal or economic; see definitions.
Type of costing	Differentiated between full or total costing and incremental costing; see definitions.
Unit cost	The cost of delivery of a single unit of immunization. The review includes four unit costs: per dose, per full immunization of a vaccine or per fully immunized child (FIC), per person in the target population, per capita.

ANNEX 3. METHODS CRITERIA FOR IDENTIFYING COMPARABLE UNIT COSTS

Criteria	Options
Mandatory Comparability Criteria	
Type of costs	Economic, financial, or fiscal costs
Type of costing	Full costing or incremental costing
Timeframe of costs	Introduction/startup costs, recurrent/ongoing costs, or both
Highest level of costs included	National, provincial, district, facility site, etc. (We do not compare small-scale demonstration project costs with programs being implemented nation-wide, as cost estimates will likely vary due to economies of scale, etc.)
Supply chain only costs	Yes (includes supply chain only cost categories) or No (includes the broader set of cost categories)
Delivery platform	Routine, supplementary immunization activity (SIA), or both routine and SIA
Delivery scale	Pilot/project or full scale
Additional Comparability Criteria – Methods	
Number of sampled facilities	
Perspective	Donor, government, provider, societal
Number of included cost categories	Total number of 15 total categories
Important cost categories included	Paid human resources; Cold chain equipment and their overheads (installation, energy, maintenance, repairs); Vehicles, transport and fuel; Training and capacity building (all Yes or No)
Additional Comparability Criteria – Vaccine delivery and context	
Vaccines costed	HPV, Rotavirus (2 doses), multiple vaccines, etc.
Number of antigens costed	Between 1 and 13
Mode of administration	Oral or injectable (for single vaccines)

Number of contacts with the health system	Between 4 and 10 contacts that the immunization schedule requires with the health system (for unit costs reporting multiple vaccines and full costs). We use number of contacts with the health system as a proxy for vaccination schedules or number of antigens costed.
Target delivery population	10-year-old girls, birth cohort, infants, newborns, older children/adolescents, other (multiple choices), under 1s, unvaccinated children, not reported or unclear
New vaccine introduction status	Yes or No
Vaccine delivery strategy	Health facility (fixed site), school, outreach, mobile, campaigns, national immunization day/week or child health day/week
Delivery sector	Public; Public and NGO; Public, Private and NGO; not reported
Additional Comparability Criteria – Context	
Country and number of countries used	All countries for which data are available in the IDCC
Region	East Asia and the Pacific, Europe and Central Asia, Latin America and Caribbean, Middle East and North Africa, South Asia, Sub-Saharan Africa
Country income level	Low income, Lower middle income, Upper middle income
Population size	< 10 million, 10 million to < 50 million, 50 million to <100 million, 100 million to <1 billion, 1 billion+
Population density	<25 persons/km^2, 25 to <75 persons/km^2, 75 to <150 persons/km^2, 150 to <500 persons/km^2, 500+ persons/km^2
Geographic setting	Rural, urban, mountainous, etc.

ANNEX 4. HOW TO INTERPRET IMMUNIZATION DELIVERY UNIT COST RANGE

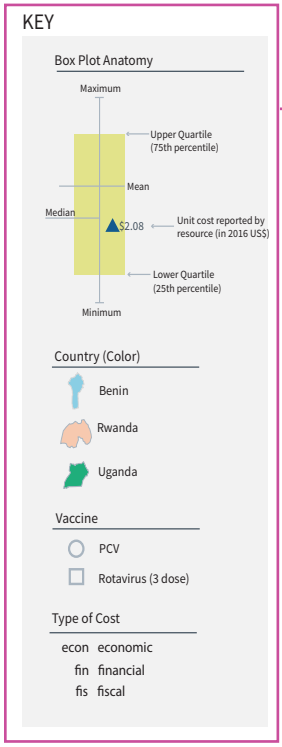
What does this **title** mean?

The **title** identifies the immunization delivery unit cost range(s) (e.g. pooled unit cost range(s)) depicted in the figure by type of costing (full/incremental), what type of vaccine(s) the range applies to (single, newly introduced vaccines, full schedules or specific vaccines such as HPV) and what costs are included (introduction/startup, recurrent/ongoing or both). The currency and year are also noted.

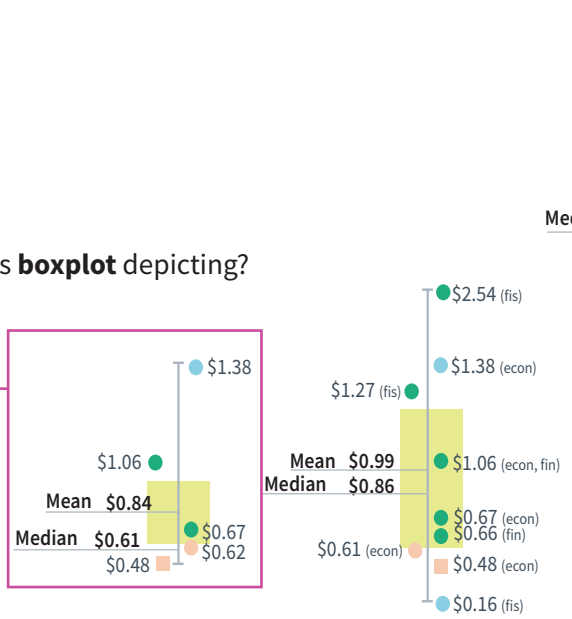
Incremental cost of single, newly introduced vaccines, excluding vaccine cost (2016 US$)

What is in **key**?

The **key** explains the box plot, the color coding and use of symbols in the figure



What is this **boxplot** depicting?



UNIT COST (excluding vaccine cost)	Economic cost per dose	Economic, financial and fiscal cost per dose	Economic cost per full immunization of a vaccine (3 doses)
DELIVERY STRATEGY	Health facility (fixed site) (routine delivery, not SIA)		

Each **boxplot** figure depicts a pooled unit cost range. The symbols indicate individual unit costs that are part of the unit cost range. Bolded unit costs are the mean and median. Similar unit cost ranges are presented side-by-side to allow for easy identification of differences between the unit costs which may explain cost variation.

What is this **bottom section** presenting ?

The **bottom section** identifies the type of unit cost each box plot figure depicts and the delivery strategy(ies) represented by the individual unit costs used in the unit cost range.

This pooled unit cost range includes five individual immunization delivery unit costs, indicated by the colored symbols. They are:

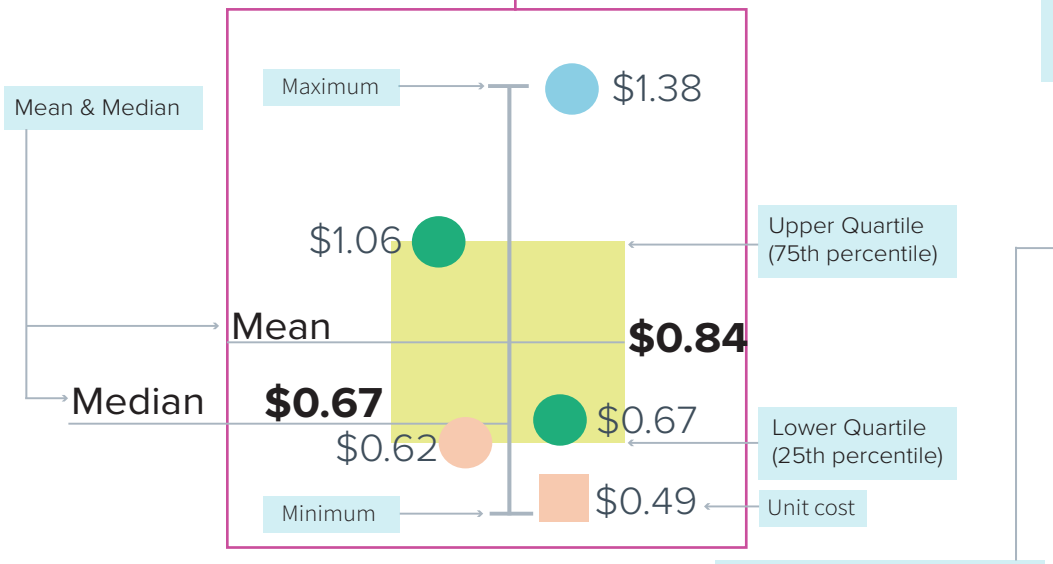
- $1.38 (blue circle, blue indicating the unit cost is from Benin, circle indicating it's for PCV vaccine)
- $1.06 (green circle, Uganda, PCV)
- $0.67 (green circle, Uganda, PCV)
- $0.62 (peach circle, Rwanda, PCV)
- $0.49 (peach square, Rwanda, Rotavirus (3 dose))

The mean is $0.84 and the median $0.67. The 25th and 75th percentile values are roughly indicated by the tan box. Please see table X for the exact values. The maximum individual unit cost estimate ($1.38) and minimum ($0.49) are indicated by the box plot end lines.

Example Cost Range

How to interpret the data points?

Text in the blue boxes defines the anatomy of the boxplot.



Shape signifies the vaccine type
Color denotes the country

EXAMPLE KEY

Country (Color)

- Rwanda
- Uganda
- Benin

Vaccine Type

- Rotavirus (3 dose)
- PCV

UNIT COST (excluding vaccine cost)	Financial cost per dose
DELIVERY STRATEGY	Health Facility (fixed site) (routine delivery, not SIA)

How to interpret these results?

The **bottom section** shows cost range is the economic cost per dose, excluding vaccine cost. It's applicable for health facility (fixed site), routine delivery (not SIA).

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THINKWELL

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