Cost-Effectiveness Analysis:
Partners in Health – All Babies Count

Evaluating Saving Lives at Birth (E-SL@B)

Report, August 2020

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Acronyms and Abbreviations

ABC	All Babies Count
CEA	Cost Effectiveness Analysis
CPAP	Continuous Positive Airway Pressure
DALY	Disability-Adjusted Life Year
GCC	Grand Challenges Canada
GDP	Gross Domestic Product
MOH	Ministry of Health
PIH	Partners in Health
PV	Present Value
QI	Quality Improvement
R&D	Research and Development
USD	United States Dollars
USAID	United States Agency for International Development
YLS	Years of Life Saved
YLL	Years of Life lost

Executive Summary

This report presents the cost-effectiveness analysis (CEA) of a Saving Lives at Birth (SL@B) funded innovation – All Babies Count (ABC) – in Rwanda. ABC is an 18-month change acceleration program focused on training healthcare providers on the Rwandan National Neonatal Care Protocol to reduce preventable neonatal deaths. The CEA presented in this report quantifies the health and social impact of scaling up the ABC program over the period, 2019 to 2030 in Rwanda.

Data on the cost of implementing ABC in Rwanda were collected from Partners in Health (PIH), while impact estimates were obtained from models developed by Grand Challenges Canada (GCC), and reviewed by Duke University. Together, these data were used to estimate three incremental cost effectiveness ratios at 3% discount rate: **1) incremental costs per new beneficiary exposed to ABC, 2) incremental costs per newborn life saved, and 3) incremental costs per year of life saved.** The estimated total cost of scaling up PIH's ABC program to reach around 2 million neonates is $6.6 million (in 2019 current USD). This translates to 10,239 newborn lives saved and 302,869 years of life saved over the period 2019 to 2030. The incremental cost effectiveness ratios estimated are $3.18 per beneficiary reached, $650.89 per newborn life saved, and $22.00 per year of life saved (i.e. 2.8% of Rwanda's GDP per capita in 2018). The WHO-CHOICE criteria suggest that interventions are "very cost-effective" if the incremental cost-effectiveness ratio (ICER) of cost per disability-adjusted life years (or cost per years of life saved in this case) is less than the country's GDP per capita, "cost effective" if it is between one and three times the country's GDP per capita, and "not cost-effective" if it is greater than three times the country's GDP per capita. Therefore, the result suggests that scaling up access to PIH's ABC model across Rwanda is *very cost effective* and could make important contributions to the reduction in infant mortality in the country.

Introduction

For every 1,000 live births in Rwanda, there are 20 neonatal deaths (National Institute of Statistics of Rwanda (NISR) [Rwanda], Ministry of Health (MOH) [Rwanda], and ICF International. 2015, 2014-15, p. 103). In order to address this high mortality rate, Partners in Health (PIH) designed the All Babies Count (ABC) program in collaboration with the Rwandan Ministry of Health in 2013. **ABC is an 18-month long multi-component program that includes training and mentorship, systems-strengthening initiatives, and quality improvement strategies to improve health centers and hospitals within the Rwandan healthcare system.** The training sessions focus on promoting best practices in providing antenatal and neonatal care and delivery services according to the Rwandan National Neonatal Care Protocol. The training sessions are further strengthened through continuous clinical mentorship and quality improvement coaching. The clinical mentorship component provides an opportunity to translate knowledge acquired in the training sessions into practice. The combination of courses and bedside training equips providers (nurses, midwives, doctors, anesthetists) with the necessary knowledge and skills to provide newborn care in alignment with the national protocol (Ministry of Health, 2018). The other components of the ABC program, system strengthening and quality improvement strategies, entail a quarterly Learning Collaborative session for all ABC participating hospitals. The Learning Collaborative sessions are comprised of an interdisciplinary team of clinicians, leadership, and Monitoring and Evaluation (M&E) teams from health centers and hospitals. This team is tasked with developing quality improvement strategies and metrics, implementing the strategies, sharing experiences upon testing these strategies, as well as discussing challenges and achievements to come up with better solutions to address the antenatal and neonatal healthcare gaps in their respective facilities.

The ABC program was implemented in two phases between 2013 and 2019. During its validation phase (2013-2015), the program was implemented in two hospitals and 23 health centers spanning two districts. During its scale-up phase (2017-2019), the program was implemented in seven hospitals, 69 health centers, and two health posts spanning four districts. PIH is continuously working with the Rwandan government to expand the ABC program nationwide (30 district hospitals and accompanying lower-tiered facilities) by 2030 and to fully transition the program to the government by 2023. **This cost-effectiveness analysis was conducted in order to assess the potential health and economic benefits of these scale up efforts in Rwanda.**

Cost-effectiveness Analysis Approach

A decision-analytic framework is used to model costs and benefits of scaling up the Partners in Health's (PIH) All Babies Count (ABC) model within Rwanda's health facilities over a twelve-year period between 2019 and 2030. Cost data was collected from PIH using a costing tool developed by Duke University with support from SL@B program partners (USAID and GCC). Health estimates were obtained from an impact model developed by Grand Challenges Canada (GCC) and validated and reviewed by Duke University. The following sections describe in detail the data sources, analytic approach, and results from the CEA.

Estimation of Costs

Using Duke's costing tool[1], **PIH categorized their costs into eight expense categories**: (1) personnel, (2) training, (3) travel and transportation, (4) supplies, (5) marketing and branding, (6) meetings, (7) research and development, and (8) facilities and overheads. Cost data was converted into United States Dollars (USD) from Rwandan Franc by the innovator using the assumed 2019 (current USD) exchange rate of 900 Rwandan Francs to 1 USD (as on April12, 2019) (Exchange Rates, 2019).

Since cost data was collected from PIH's internally generated estimates, it is important to note that it reflects certain key assumptions about PIH's scale-up strategy. For example, PIH plans to integrate the ABC program with the Rwandan MOH operations starting in 2023. Although some PIH staff will continue to support the program during the transitional period between 2023 and 2024, starting 2025, the MOH technical and support staff will completely take over the operations and support the ABC program as part of their routine duties. The MOH staff effort will be covered by the MOH budget after 2023 as the program is integrated into the government system. Therefore, the personnel costs will become almost constant as there will not be any extra cost other than the salaries MOH staff already receive. PIH expects that after the complete adoption of the program by the MOH, the salary costs for the government will mainly be incurred for QI (Quality Improvement) advisors, moto drivers, and mentors. The meetings and facilities (mainly the rental space) costs are assumed to reduce after 2023 as the rental space will be shared across different government programs, and existing facilities upon integration. The innovator, however, expects that training costs will be incurred even after the integration of the program within the MOH as training is an important component of the program and will need to be continued by the Ministry. The innovator also anticipates that the research and development (R&D) costs will end by 2023, after the integration of the program with MOH. Going forward, the main focus will be implementation rather than any R&D activities. PIH also anticipated that costs would continue to increase from 2019 to 2021 with 2021 seeing major expenses as many facilities will be up and running, and a few new facilities will be opening as implementation sites. Therefore, in 2021, the innovator assumes high expenses in important cost categories of salaries, trainings, and supplies. The innovator projected the salaries, training, and other costs after 2023 based on its current expense estimates.

Estimation of Health Impact

The health impact of the ABC program in Rwanda was estimated as the **number of beneficiaries reached, number of lives saved, and years of lives saved**. A decision-analytic framework was used and the analysis was based on the impact model developed by GCC.[2]

The impact model (see Annex 1) estimates the number of lives saved through the introduction and scale-up of the ABC model in districts across Rwanda between the years 2019 and 2030.

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[1] The costing tool allows healthcare innovators extract cost data needed for economic analysis from their organization/institution records. It also allows users to develop future cost projections. It was developed by the Duke team and pilot tested with several healthcare innovators in the SL@B program. (Dixit, et al., 2019)

[2] GCC continually updates this model. For this analysis, the Duke team used the most recent version as of May 2020. This version was further reviewed and updated by the Duke.

The lives saved were estimated assuming that the model was implemented in all public sector district hospitals and accompanying sub-tiered facilities in Rwanda.

A literature review was conducted and additional data was collected from PIH to estimate variables and parameters used to calculate the number of lives saved due to the ABC model (see Table 1). The health impact estimated is the total number of newborn deaths averted as a result of the health worker trainings, health system strengthening, and quality improvement conducted as part of the ABC model.

Table 1: Variables and Parameters Used for Estimating the Number of Lives Saved

Variable Definitions	Value Estimate (range)	References
Crude birth rate	3.21% (3.16%, 3.26%)	The World Bank, 2020
Percentage of deliveries that occur in public health facilities in Rwanda	89.90% (84%, 93.30%)	National Institute of Statistics of Rwanda (NISR) [Rwanda]; Ministry of Health (MOH) [Rwanda]; and ICF International, 2015
Neonatal mortality rate among catchment populations implementing ABC model during funding period	1.83% (1.78%, 1.88%)	Partners in Health, 2019
Neonatal mortality rate post funding period (including deaths occurring in facility and community)	1.67% (1.62%, 1.72%)	UNICEF [UN IGME], 2020
Reduction in neonatal mortality in facilities implementing the ABC model	29.83% (19.23%, 0.43%)	Partners in Health, 2019

Source: GCC Impact Model

To estimate years of life saved (YLS) by the ABC program, first, the average years of life lost (YLL) of neonates in Rwanda was calculated, then, it was multiplied by the estimated number of total lives saved due to scale-up of the ABC program. A life expectancy at birth of 69.33 in 2019 (using the life expectancy at birth for Rwanda between 2014 to 2018 as reported in the World Development indicators) and a discount rate of 3% (See Annex 2 for details) were assumed (The World Bank, 2020).

Estimation of Cost-Effectiveness Ratios

The estimates of costs and effectiveness calculated above were combined to get cost-effectiveness ratios. **The base-case for this analysis compared a scenario with national scale-up of PIH's ABC program in Rwanda to a scenario with no scale-up**. The no scale up or status quo is the situation when no new intervention similar to ABC program is introduced to reduce newborn mortality in Rwanda. Therefore, these estimates reflect incremental cost-effectiveness ratios (ICERs). ICERs were estimated since the focus of this study is on the additional costs of scale-up (and not the total or average costs). Nevertheless, scaling up availability of an innovation within a functional health system will leverage some of the resources already invested to make that system work – this study did not account for these costs already invested in the system.

The following ICERs were estimated in this CEA: **(1) incremental cost per beneficiary reached, (2) incremental cost per life saved, and (3) incremental cost per year of life saved**. Different ICERs can be used to achieve diverse objectives which resonate differently with various stakeholders. For example, from a management/operations perspective, it is important to know the incremental cost per beneficiary reached to inform decision on resource allocation, day-to-day monitoring, and for budgetary program mapping. Whereas incremental cost per life saved and cost per year of life saved are important from the perspective of the MOH and funders because they often have to select interventions that maximize health outcomes, not program coverage.

The ICERs were estimated with and without discounting, and sensitivity analysis was performed to test the robustness of the findings to changes in assumptions and model parameters. **Both deterministic and probabilistic sensitivity analyses were performed in line with existing standard practice**. In the deterministic sensitivity analysis[3], we varied the estimates of costs and health outcomes by 10 percentage point steps from +/-10% to +/-90% and computed ICERs for each combination. The probabilistic sensitivity analysis used a Monte Carlo simulation approach to sample for input parameter distributions. Details of the sensitivity analysis can be found in Annex 3.

Key Findings from the Cost-Effectiveness Analysis

Table 2 summarizes the results of the cost-effectiveness analysis of the national scale-up of the ABC program in Rwanda through 2030. For the base case, estimates without discounting and with 3% discounting are presented.[4] The findings from the sensitivity analysis conducted are also reported here.

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[3] As per the literature, sensitivity analysis is a "subjective" variation of plausible values for input variables. (Hayward Medical Communication, 2009) The sensitivity analysis allows researchers explore ranges of values that affect the results of the ICER. This exercise also relates the deterministic sensitivity results to the simulation results, and expected probability ranges, with some statistical concentration around the base values. One and two standard deviations around the mean ICER have been reported here. We find the two analyses (deterministic sensitivity and simulation) to be consistent. Therefore, in accordance with existing research practice, we conducted the deterministic sensitivity analysis with 10 percentage point increase and decrease from 10% to 90% in the inputs of the model. The ICER of cost per year of lives saved for ABC program was found to be below the per capita GDP threshold for Rwanda for the whole range of variation as per WHO's recommendation. We decided to present only the +/-20% and +/-50% deterministic variations in this report taking (Darmstadt, et al., 2008) as a reference which chose to show only +/-25% sensitivity variation in their paper.

[4] WHO's Global Burden of Disease Concept use 3% discount rate for cost-effectiveness studies in health and medicine (World Health Organization (Global Burden of Disease Concept), p. 32).

Table 2: Cost-Effectiveness Analysis (CEA)

Incremental cost per beneficiary (not discounted)	Incremental costs	7,903,287
	New beneficiaries	2,605,570
	Ratio	**USD 3.03**
Incremental cost per beneficiary (discounted at 3% per year)[5]	Present value (PV) of incremental costs @ 3% discounting	6,664,290
	PV of new beneficiaries @3% discounting	2,093,188
	Ratio	**USD 3.18**
Incremental cost per life saved (not discounted)	Incremental costs	7,903,287
	Lives saved	12,734
	Ratio	**USD 620.66**
Incremental cost per life saved (discounted at 3% per year)	Present value (PV) of incremental costs @ 3% discounting	6,664,290
	PV of lives saved @3% discounting	10,239
	Ratio	**USD 650.89**
Incremental cost per year of life saved (not discounted)	Incremental costs	7,903,287
	Years of life saved	376,859
	Ratio	**USD 20.97**
Incremental cost per year of life saved (discounted at 3% per year)	Present value (PV) of incremental costs @ 3% discounting	6,664,290
	PV of years of life saved @3% discounting	302,869
	Ratio	**USD 22.00**

Source: Authors' calculation using data from Costing Tool and GCC Impact Report

The total cost of scaling-up the ABC program in Rwanda to reach an additional 2,093,188 beneficiaries over an 11-year period between 2019 and 2030 is $6,664,290 (discounted at 3%). The total cost includes the cost of salaries (personnel), travel, conducting meetings, training, supplies, research and development, and facilities and overheads. The contribution of the different cost categories to the total cost of scale-up varied over time as shown in Figure 1. The total cost is expected to increase in 2020 because of the increase in expenditure on leadership quality improvement (QI) training, medical supplies—hospital catchment area bundle, and equipment and vehicle (motorcycle) purchase to meet the new capacity requirement as the program is scaled to new catchment areas in Rwanda.

[5] The calculation of PV or cost and beneficiary can be found in Annex 4.

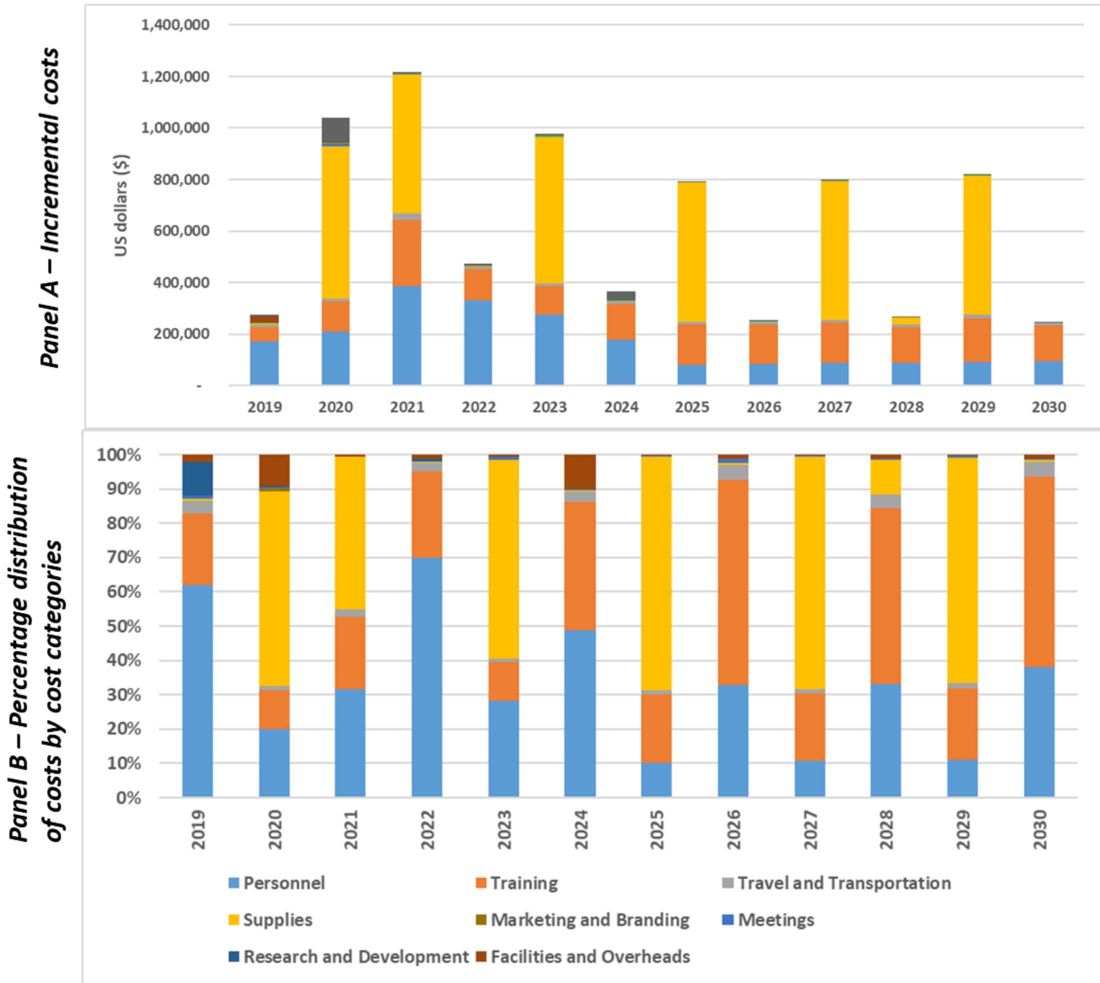
PIH assumes that the medical supplies (hospital supplies area bundle) will be purchased in alternate years to serve the new sites where the ABC program starts (Figure 1, Panel A). The main components of the medical supplies include CPAP devices, infant warmers, syringe pumps and some other essential supplies that are required for newborn care. Although, the exact contents will vary based on the specific needs of the facilities, this is a typical supply requirement per catchment area (i.e., hospitals and their referring health centers). The cost increases and decreases based on the number of catchment areas starting at different times over the implementation period. The variation of costs in alternate years is one of the scale-up scenarios assumed by the innovator. Even if the costs were more uniformly distributed until 2030, the overall cost-effectiveness results for PIH's ABC program will not change as shown in Annex 5.

Training is a crucial part of the ABC program, and hence, it captures a sizeable percentage of total cost in different years (Figure 1, panel B). According to PIH, the training modules provided under the ABC program include, Helping Babies Breathe, Advanced Neonatal Care, Helping Mothers Survive, and Leadership QI (Quality improvement) Trainings. PIH expects that the training on Helping Babies Breathe, Advanced Neonatal Care and Leadership QI trainings will be undertaken in alternate years, and this will cause a marginal increase in total training costs in 2025, 2027, and 2029.

Facilities is another area of expense during the implementation of ABC program which includes rental space, equipment, and vehicles. PIH expects that after the program gets embedded into the MOH, the rental space will be shared with other government programs. Therefore, the rental cost will be reduced starting 2024. According to the innovator, regular travel by mentors to different catchment areas is an important and crucial element of the ABC program, and the need for the travel will increase as the program expands to new areas. Therefore, PIH anticipates an expenditure of about $90,000 in 2020 to buy both vehicles and motorcycles, and anticipates that the government will need to buy 17 motorcycles for $34,000 in 2024 to implement the ABC program until 2030, with an assumption that these motorcycles will last for 5-7 years given the road conditions in Rwanda.

Meetings are another major cost category in the implementation of the program in Rwanda. Stakeholder meetings and district closing meetings are the main expense areas in this category. PIH assumes that the expenditure on stakeholder meetings will be incurred only in alternate years, whereas the district closing meeting will happen every year until 2030, and hence there will be costs involved in organizing these meetings every year.

Figure 1: Incremental Costs of Scaling up the ABC program Disaggregated by Year and Cost Category



Source: Data provided by the innovator into the Costing Tool

Over the 11-year period (2019 to 2030), scaling-up the ABC program in Rwanda to reach 2,093,188 beneficiaries will result in a total of 10,239 lives saved, and 302,869 years of life saved. The annual estimates of lives saved ranged from 230 in 2019 to 1,974 in 2030, while the annual estimates of years of life saved ranged from 6,700 in 2019 to 58,828 in 2030. See Table 3 for details.

Table 3: Annual Estimates of Life Saved and Years of Life Saved (YLS)

Years	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Lives Saved	230	213	398	602	725	915	1103	1336	1541	1757	1939	1974
YLS	6,700	6,232	11,636	17,643	21,310	26,955	32,537	39,513	45,666	52,170	57,668	58,828

Source: Authors' calculations using data from GCC impact model

For incremental cost-effectiveness ratios, an incremental cost per new beneficiary of $3.03, an incremental cost per life saved of $620.66 and an incremental cost per year of life saved of $20.97 were estimated. When a 3% rate of discount is applied, an incremental cost per new beneficiary of $3.18, an incremental cost per life saved of $650.89, and an incremental cost per life-year saved of $22 (i.e. 2.8% of gross domestic product (GDP) per capita) were estimated for Rwanda's ABC program.

The results of the sensitivity analysis are summarized in Table 4. A +/-20% variation in the estimates of costs and lives-saved results in minimum and the maximum values of cost per life saved of $434 and $976. Using a variation of +/- 20% on cost and YLS leads to a minimum and maximum cost per years of life saved of $15 and $33 respectively. Increasing the variation of the input parameters of cost and life saved to +/-50% results in an increase in the maximum value of cost per life saved and cost per years of life saved to $1,953 and $66 respectively, and a reduction in the minimum value of cost per life saved and cost per years of life saved to $217 and $7, respectively.

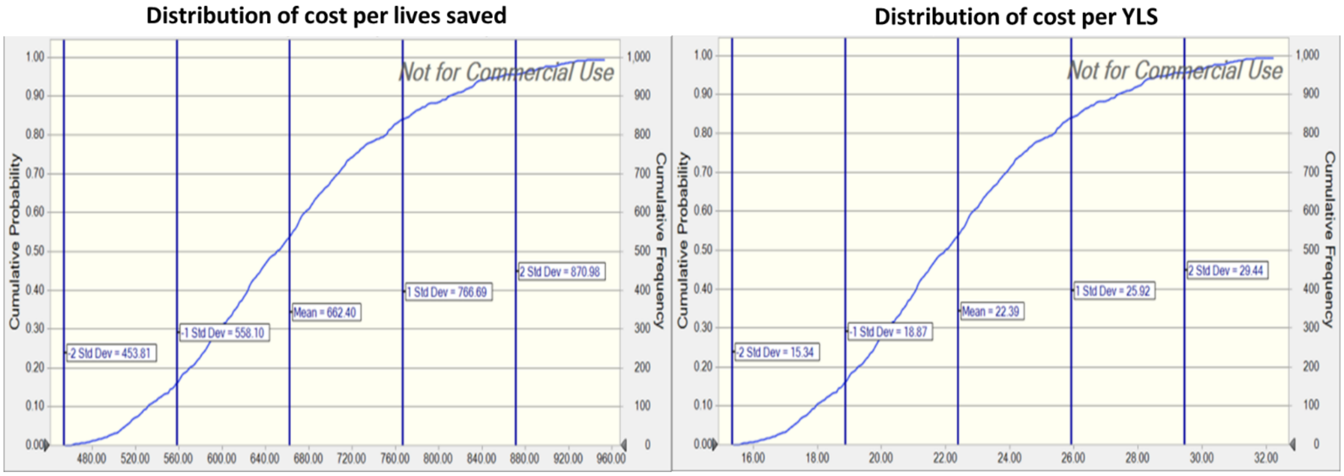
Table 4: Results of Sensitivity Analysis Using Deterministic Analysis (in 2019 USD)

Cost Per Life Saved			
+/ - 20 percent			
Summary	Costs	Lives Saved	Cost/Life saved
-20% cost, +20% lives saved	5,331,432	12,286	**$434**
+20% cost, -20% lives saved	7,997,148	8,191	**$976**
+/ - 50 percent			
Summary	Costs	Lives Saved	Cost/Life saved
-50% cost, +50% lives saved	3,332,145	15,358	**$217**
+50% cost, -50% lives saved	9,996,435	5,119	**$1,953**
Cost Per YLS			
+/ - 20 percent			
Summary	Costs	YLS	Cost/YLS
-20% cost, +20% YLS	5,331,432	363,443	**$15**
+20% cost, -20% YLS	7,997,148	242,295	**$33**
+/ - 50 percent			
Summary	Costs	YLS	Cost/YLS
-50% cost, +50% YLS	3,332,145	454,304	**$7**
+50% cost, -50% YLS	9,996,435	151,435	**$66**

Source: Authors' calculation using GCC Impact model and Costing tool

Similar results were obtained when probabilistic sensitivity analysis was conducted (see figure 2). The mean cost per years of life saved was $22.39 (95% CI: $15.34, $29.44). Based on the cumulative probability distribution of cost per years of life saved, this means that there is 95% certainty that the cost per year of life saved will be between $15.34 and $29.44. The mean cost per life saved was $662.40 (95% CI: $453.81, $870.98). Similarly, based on the cumulative probability distribution of cost per life saved, this means that there is 95% certainty that the cost per life saved will be between $453.81 and $870.98.

Figure 2: Results of Sensitivity Analysis Using Probabilistic Analysis (in 2019 USD)



Source: Authors' calculation using GCC Impact model and Costing tool

In addition, sensitivity of individual parameters in Table 1 was also conducted to identify which parameters had the highest impact on cost per year of life saved, while keeping all other parameters constant. The top three parameters whose variability affected cost per year of lfife saved were **1) Reduction in neonatal mortality in facilities implementing the ABC model 2) Neonatal mortality rate (2017) including community NMR, and 3) Percentage of deliveries that occur in public facilities in Rwanda.** These variables combined explain, according to sensitivity analysis, about 92% of the variability of cost per YLS. Therefore, the innovator should pay extra attention to these parameters from the impact model while expanding the innovation to new areas.

Implications of Key Findings

The results of this study suggest that **a national scale-up of the ABC program by PIH and the MOH to reach additional beneficiaries in Rwanda would be cost-effective**. The findings suggest that the life of one additional newborn would be saved for every $651 spent scaling up the ABC program in Rwanda. This translates to an additional year of life saved for every $22 invested in scale-up efforts. The estimates of incremental cost per life-year saved ($22) fall **below the GDP per capita for Rwanda[6], suggesting that scale-up will be *very cost-effective* according to commonly used criteria for cost-effectiveness**.[7] Moreover, our estimate of incremental cost per life-year saved is 2.8%[8] of Rwanda's GDP per capita which compares favorably with estimates from life-saving interventions in other LMICs (Low- and Middle-Income Countries). For example, Memirie and colleagues analyzed scale-up of maternal

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[6] Rwanda's 2018 GDP per capita (current USD) was $772.94. (The World Bank, 2020).

[7] The WHO-CHOICE criteria suggest that interventions are "very cost-effective" if the cost per life-years saved ICER is less than the country's GDP per capita, "cost effective" if the ICER is between one and three times the country's GDP per capita, and "not cost-effective" if the ICER is greater than three times the country's GDP per capita.

[8] Although the WHO-CHOICE criteria referred to Disability Adjusted Life Years (DALYs), but if an intervention is found to be cost-effective using the more conservative years of life lost (or years of life saved (YLS)), then the intervention will also be cost-effective if DALYs were used.

and neonatal health interventions in Ethiopia (GDP per capita of $772.31), a country in the same region and with a very similar per capita GDP as Rwanda (The World Bank, 2020), and estimated incremental costs per DALYs averted that ranged from $7 to $300. When measured as a percentage of GDP per capita of Ethiopia in 2018, their estimates ranged from 1% to 39% (Memirie, et al., 2019). Similarly, Goldie and colleagues analyzed scale-up of a package of maternal interventions in India, and estimated incremental costs per year of life saved that ranged from $150 to $350. When measured as a percentage of GDP per capita of India in 2018[9], their estimates ranged from 14% to 33% (Goldie, Sweet, Carvalho, Natchu, & Hu, 2010). A similar study (Erim, Resch, & Goldie, 2012) on the scale-up of interventions to prevent pregnancy-related deaths in Nigeria estimated the incremental costs per years of life saved for most of the interventions below $500, which was about 22% of Nigeria GDP per capita in 2019[10].

However, being cost-effective does not automatically mean that an intervention will be affordable. Affordability depends on the ability of the payer to bear the costs of scaling up. According to the cost projections, the annual cost needed during the scale up period vary from $1.2 million in 2020, to 793 thousand in 2025, and $249 thousand in 2030, and a payer will need to evaluate its ability to pay for the costs of scale-up.

Limitations of the Study

The assessment of cost effectiveness for the ABC program in Rwanda is based on cost information provided by the innovator, PIH, and the impact model created by GCC and reviewed by Duke. **Collection of independent primary data through market research and pilot impact studies**, which goes beyond the scope of the current study, could strengthen the analysis. Moreover, the cost data is projected by the innovator based on the current expense information, and assumptions of future integration of the program with MOH. These assumptions need to be continually evaluated, and the future implementation data should be accordingly updated.

The present incremental cost-effectiveness analysis is based on the **comparison of the ABC program with the status quo**. The status quo in this scenario means that all ongoing efforts by the MOH and other private actors will remain the same, and no new intervention similar to ABC will be introduced to reduce newborn mortality in Rwanda.

The impact model currently does not take into consideration the change in neonatal mortality rates (NMR) in comparison sites, or districts where the ABC model has not been piloted. The unavailability of the NMR estimates from the pilot study would overall lead to an overestimation of the lives saved number. The model also uses the breakdown of the number of deliveries occurring across various health facilities from the 2010 Rwandan Health Statistics Booklet (2010 HMIS data). This data source does not contain estimates of the number of deliveries occurring across health posts – a particular kind of health facility that operates in Rwanda. Data availability of more recent delivery estimates can thus further strengthen the analysis.

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[9] India’s 2018 GDP per capita was $2,009. (The World Bank (World Development Indicators), 2020)
[10] Nigeria’s 2019 GDP per capita was $2,230. (The World Bank (World Development Indicators), 2020)

The model also estimates mortality, and not morbidity, in its calculation of the years of lives saved due to the ABC model. Estimating the morbidity would require assumptions and data on ABC's impact on the quality of health services and improvement in outcomes which is currently not available via the pilot study being conducted for the innovation. Furthermore, not including morbidity in the impact model makes the model more conservative as it underestimates the overall impact of ABC program in Rwanda.

Conclusion

The planned scale-up of ABC program to all the district hospitals and accompanying lower-tiered facilities in Rwanda between 2019 and 2030 would potentially save many newborns lives, and would be *very cost-effective* according to existing thresholds for measuring cost-effectiveness. Over the period, **this scale-up effort will require a total investment of about 6.7 million USD, reach 2.1 million beneficiaries, save about 10,000 newborn lives, and contribute to over 303,000 years of life saved**. PIH's cost structure is expected to change during the expansion with personnel, meeting, and facilities costs, reducing after 2023 when the government takes over the operations. Training costs are an important component of the ABC program and will not vary much during the scale up of the model. PIH also expects that medical supplies/hospital catchment area bundle cost will be incurred every alternate year during the scale-up. Overall, these results provide reliable quantitative evidence that scaling up the ABC program could save the lives of many newborns in Rwanda.

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Annexures

Annex 1: Lives Saved Calculation in GCC Impact Model

The following tables provides the GCC impact model which calculates the lives saved from the scale-up of ABC program by PIH from 2019 to 2030 in Rwanda.

Access	TOTAL	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Total Population		12,374,398	12,663,117	12,955,768	13,252,274	13,552,034	13,854,856	14,160,550	14,468,759	14,779,043	15,090,251	15,401,596	15,712,647
Total number of births		396,748	406,005	415,388	424,894	434,505	444,214	454,016	463,897	473,846	483,824	493,806	503,779
Number of districts covered	30	4	0	3	3	2	3	3	3	3	3	3	0
Cumulative number of districts		4	4	7	10	12	15	18	21	24	27	30	30
Number of births in catchment population (discounted deliveries occuring in referral and provincial hospitals)	2,898,298	46925	48020	89652	135920	164156	207627	250621	304350	351744	401858	444227	453198
Number of births occurring in public facilities (discounting for home deliveries and deliveries in private facilities)	2,605,570	42186	43170	80597	122192	147576	186657	225308	273610	316218	361270	399360	407425
Outcomes	**TOTAL**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Number of deaths averted as a result of the implementation of the ABC model (includes NMR trend)	12,734	230	213	398	602	725	915	1103	1336	1541	1757	1939	1974

Source: GCC Impact Model

Annex 2: Future Life Stream of Individuals who are Saved or YLS, and the Total PV of YLS (or NPV)

Years	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Life expectancy at birth (L)	69.3311	69.8320	70.3365	70.8447	71.3565	71.8721	72.3913	72.9144	73.4412	73.9718	74.5062	75.0445
Total Life Saved (N)	229.9111	213.3883	398.3916	601.5864	725.1101	915.3021	1102.6288	1336.3406	1541.3601	1757.4446	1938.8582	1974.0677
Individual YLL-- ((1/r) *(1-e^(-r*L)))	29.1422	29.2045	29.2664	29.3277	29.3886	29.4489	29.5088	29.5681	29.6270	29.6853	29.7432	29.8005
YLS (Years of Life Saved)	6700.113304	6231.90123	11659.4692	17643.14217	21309.93443	26954.64939	32537.21965	39513.09269	45665.8591	52170.3485	57667.82966	58828.25896
PV of YLS for individual years (YLS*1/ (1+r) ^t)	6,700.1133	6,050.3895	10,990.1680	16,145.9744	18,933.6007	23,251.3173	27,249.4092	32,127.7602	36,049.0509	39,984.2280	42,910.2811	42,498.7859
Total PV of YLS (NPV)	302,891.0787											

Source: Authors' calculation using GCC Impact Model and Costing Tool

Note: Only four decimal places are presented in the table. However, there are more decimal numbers in the Excel calculation, which are not shown here. Therefore, there is some variability in the calculation of YLS (i.e. multiplication result of life saved and YLL)

This CEA calculates YLS using the life saved numbers, and utilizes the following formula to estimate the future life streams of an individual or YLL for an individual for each year – 2019 to 2030 (Bruce A Larson, 2013):

YLL=(1/r) *(1-e^(-r*L))

where r is the discount rate of 3% to years of life lost in future (as suggested by (World Health Organization (Global Burden of Disease Concept)), L is the standard expectation of life, and e is equivalent to 2.71.

This CEA pertains to newborn deaths, therefore, the life expectancy (L) at the time of birth is used for calculating YLL for each year. Moreover, the future life streams of the individuals who are saved or YLS for each year from 2019 to 2030 is obtained by multiplying the calculated YLL from the above equation with the corresponding lives saved number (N) in that year as shown in the following formula:

YLS = Lives saved (N) * average YLL

YLS= N * (1/r) *(1-e^(-r*L))

The Net Present value (NPV)[11] of the YLS is calculated by discounting the YLL for each year from 2019 to 2030 at 3% to bring the future life streams of individuals saved to 2019. The calculations and final values of life saved and YLS are shown in the table above.

Annex 3: Sensitivity Analysis

The cost and YLS, and life saved information has a tendency to vary, and might not remain the same as the current estimates. These values could increase or decrease, and the variations in these parameters will impact the incremental ratios, thus altering the cost-effectiveness of the innovation calculated based on current projections. To that end, the cost-effectiveness of the expansion of ABC program by PIH in Rwanda was pressure-tested by conducting sensitivity analysis to understand how changes in input parameters/assumptions could affect cost per YLS, and to assess if ABC program remains a cost-effective innovation in Rwanda under different parameter variations. Two types of sensitivity analysis (deterministic and simulation) were conducted; both approaches are described below.

[11] Net present value (NPV) is used to calculate what future values/returns are worth today. We use a discount rate to calculate the present value of future flows of a project. For the health and medicine projects, WHO uses a discount rate of 3% to convert future values into the present values. The addition of all the present values for different years gives the NPV.

1. Deterministic Sensitivity Analysis

The deterministic sensitivity analysis was used to obtain the widest range of possible uncertainly to test the cost effectiveness of ABC program in Rwanda. This method of sensitivity analysis only varies the cost and YLS by a fixed amount, and does not change individual parameters. Although this analysis does not include the range of upper and lower limits of all the assumptions as the probabilistic analysis, it still provides a broad direction on whether the innovation remains cost effective at larger, more unexpected, variations in cost and YLS. As mentioned earlier, deterministic sensitivity analysis was conducted from +/-10% to +/-90 for both the cost and YLS. **The innovation was cost effective for all the variation in this range as per the WHO criteria[7].**

The study by (Darmstadt, et al., 2008) used a sensitive range of +/- 25 % to calculate the cost per life saved. Therefore, taking the paper as the reference, this CEA first varied the cost and YLS (and life saved) by +/-20%. The effectiveness of ABC program was further pressure tested by +/-50 variation; the calculation for this value is also presented here. The following paragraphs describe the steps taken for each variation of the sensitivity analysis.

a. +/- 20 % variation

In this case, the minimum and maximum estimates of cost and YLS (and life saved) were calculated as follows by varying both these parameters by +/- 20 %.

- Lower end of cost per YLS (and life saved) = obtained by, Minimum value of calculated cost / Maximum value of YLS (and life saved).
- Higher end of cost per YLS (and life saved) = obtained by, Maximum value of calculated cost / Minimum value of YLS (and life saved).

The minimum and maximum values of cost per life saved are also calculated using the same methodology.

b. +/- 50 % variation

In this case, the minimum and maximum values of cost and YLS (and life saved) are calculated by varying both these parameters by +/- 50%. A similar calculation, as explained for +/- 20% variation, is followed to obtain the minimum and maximum values of cost per YLS (and life saved).

2. Probabilistic Sensitivity Analysis

Sensitivity analysis using the Monte Carlo simulation (10,000 simulation runs) was done to understand the variations in cost per YLS (and life saved). In this case, important assumptions used in the GCC impact model, and the cost provided by PIH are varied. Table 1 (from the main report) provides the list of assumptions and ranges used for the probabilistic analysis. These ranges are based on literature review, and in some cases, assumptions have been made by experts at GCC and PIH due to lack of information. The cost provided by the innovator was assumed to vary by a maximum of 10% standard deviation for the simulation due to increase/ decrease in the market, or other uncertainties in the implementation of ABC program. Normal distributions were assumed for most of the input assumptions that affect the YLS (and number of lives saved) as well as variability for the costs of provision, with ranges of possible observations of two standard deviations from the mean. The analysis is based on incorporating the uncertainty induced by the variation of each input parameter in the cost per YLS model using the technique of Monte Carlo simulation.

Annex 4: PV Calculation of Cost and Beneficiary

Years (t)	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Beneficiaries (B)	42,186	43,170	80,597	122,192	147,576	186,657	225,308	273,610	316,218	361,270	399,360	407,425
PV for B for individual years (@ r=3%) (B*1/(1+r)^t)	42,186	41,912	75,971	111,823	131,120	161,012	188,692	222,470	249,626	276,884	297,161	294,333
Total PV of Beneficiaries	2,093,188											

Years (t)	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Cost (C0.)	212,829.5	712,610.2	851,864.6	409,949.9	959,434.0	372,091.8	827,041.3	294,407.1	1,061,013.7	407,876.7	1,371,719.7	422,448.3
PV for C0. for individual years (@ r=3%) (C0. *1/(1+r)^t)	212,829.53	691,854.56	802,964.11	375,162.22	852,444.70	320,969.63	692,634.11	239,379.93	837,574.03	312,603.50	1,020,688.30	305,185.64
Total PV of Cost	6,664,290											

Source: Authors' calculation using GCC Impact model and Costing tool

The incremental cost per beneficiary was obtained using the simple average costs and simple average beneficiary information. However, it is recommended practice to use the discounted costs and discounted number of beneficiaries for the same period of analysis using the same discount rate to obtain the PV (Edejer, et al., 2003, p. 69). The PV of costs, and beneficiaries are calculated to get the value of future streams of the cost and beneficiaries in 2019. To get the total PV in 2019, the following formula was applied to cost, and beneficiaries in each year from 2019 to 2030, and then all the discounted values for each year were added to get the total PV for cost and beneficiaries, respectively (Bruce A Larson, 2013).

PV = (Cost / Beneficiary) *1/ (1+r) ^t (r= discount rate, t= time from 2019)

Discounting both the cost and the number of beneficiaries with a 3% rate of discount (using the same discount rate as recommended by WHO for discounting YLS), the incremental cost and incremental beneficiaries at USD 6.7 million and 2.1 million respectively were obtained.

Annex 5: ICERs when costs are assumed to be uniformly distributed during the scale-up

		Old Estimate	New Estimate	Percentage change
` Incremental cost per beneficiary (not discounted)	Incremental costs	7,903,287	8,567,621	
	New beneficiaries	2,605,570	2,605,570	
	ratio	**3.03**	**3.29**	**8.41%**
Incremental cost per beneficiary (discounted at 3%)	Present Value (PV) of incremental costs @ 3%	6,664,290	7,048,936	
	PV of new beneficiaries @3%	2,093,188	2,093,188	
	ratio	**3.18**	**3.37**	**5.77%**
Incremental cost per life saved (not discounted)	Incremental costs	7,903,287	8,567,621	
	Lives saved	12,734	12,734	
	ratio	**620.66**	**672.84**	**8.41%**
Incremental cost per life saved (discounted at 3%)	Present Value (PV) of incremental costs @ 3%	6,664,290	7,048,936	
	PV of lives saved @3%	10,239	10,239	
	ratio	**650.89**	**688.46**	**5.77%**
Incremental cost per year of life saved (not discounted)	Incremental costs	7,903,287	8,567,621	
	Years of life saved	376,859	376,859	
	ratio	**20.97**	**22.73**	**8.41%**
Incremental cost per year of life saved (discounted at 3%)	Present Value (PV) of incremental costs @ 3%	6,664,290	7,048,936	
	PV of years of life saved @3%	302,869	302,869	
	ratio	**22.00**	**23.27**	**5.77%**

The above table shows different ICERs of the ABC program based on a uniform distribution (new estimate) and non-uniform distribution (old estimate) of cost during the scale up period until 2030. The above table shows that the comparison of ICERs between new and old estimates are not very different. The new estimate of cost per years of life saved, $23.27, is just 5.77% more than the old estimate, and the value is still much below the GDP per capita of Rwanda. Therefore, **PIH ABC program remains a very cost-effective intervention in Rwanda even when the costs are uniformly incurred over the years**.