Supplemental material 19. Results Chapter 4 publication

A decision-tree model to evaluate the impacts of workforce investments aimed at strengthening Emergency Obstetric and Neonatal care (EmONC) facilities in Burundi

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Abstract

Introduction

To achieve the 60% and 50% reductions in maternal and newborn mortality rates that Burundi pledged to attain by 2030, this country must rationalise its limited resources and address inefficiencies within its healthcare system. We developed four workforce investment scenarios aimed at strengthening emergency obstetric and neonatal care (EmONC) facilities, predicting the costs and benefits associated with each proposal over the 2025-2030 timeframe.

Methods

We documented across the 112 Burundian EmONC facilities the available human resources and collated annual data on deliveries and obstetric complications covering 2021. Using the Workload Indicator for Staffing Needs (WISN) methodology, we estimated for each facility the workforce deficit and developed four EmONC workforce investment scenarios; no investment, a partial workforce package, and full workforce packages targeted at either all facilities or a select group of priority facilities. A decision tree model helped to predict the costs per maternal death averted.

Results

A budget of US$ 11.1 million is required to fully address workforce gaps across the 104 facilities with shortages over five years, potentially saving 532 maternal lives each year. Given budget constraints, Burundi could focus on the 24 priority facilities with an investment of US$ 3.27 million or allocate US$ 3.18 million to supply two midwives across the 104 facilities. These investments are projected to avert 163 and 267 maternal deaths annually, respectively. The partial workforce investment is more cost-effective with an expected expenditure of US$ 2,380.58 for each maternal life saved.

Conclusion

Efforts to invest across the EmONC network if simply based on assigned B/CEmONC status may poorly allocate scarce resources. If resources are limited, investing in two additional midwives across the 104 EmONC facilities would be more efficient than implementing a full workforce package. However, health benefits of any workforce investment significantly depend on an enabling environment.

Keywords: EmONC, workforce, Workload Indicator for Staffing Needs (WISN), Decision Tree, Burundi

WHAT IS ALREADY KNOWN ON THIS TOPIC

- Persistent poor resource allocation is a key factor driving inefficiencies in healthcare systems in low- and middle income countries (LMICs) including Burundi.
- In these countries, resource allocation is often based on normative policies that inadequately consider service delivery patterns and health outcomes, failing to account for the potential benefits of such investments.

WHAT THIS STUDY ADDS

- Our findings reveal that workforce gaps across Burundian emergency obstetric and neonatal care (EmONC) facilities are variable, pointing to severe health worker shortages and maldistributions.
- In collaboration with Burundian stakeholders we developed four EmONC workforce investment scenarios demonstrating the costs and potential benefits of each proposal, an invaluable information for Burundian health policymakers and development partners seeking to optimise the allocation of limited health resources.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

- This study illustrates how routine data can be effectively leveraged to support policymakers in making informed decisions aimed at improving efficiency and effectiveness of human resource investments specifically within Burundi's EmONC network.

Introduction

In 2017, Burundi established the Emergency Obstetric and Neonatal Care (EmONC) network which comprises 53 hospitals and 59 primary health facilities designated as comprehensive (CEmONC) and basic (CEmONC) EmONC facilities, respectively.[1,2] Although these 112 EmONC facilities represent less than 8% of health facilities nationwide, they reportedly perform one third of the 85% of deliveries occurring in health facilities[3] and manage nearly two-thirds of obstetric complications.[4,5] The creation of this specialised maternity network materialised decades of national commitment to improving maternal and newborn survival through investments in obstetric care, particularly for emergency complications.[6-9] This EmONC programme is supported by a specific policy that defines how facilities should be strengthened with appropriate resources to maximise their readiness to provide quality care for emergency obstetric and newborn complications.[5,10,11]

Despite this political commitment, the Burundian EmONC network faces significant capacity challenges that hinder the delivery of quality maternal and newborn care. Previous estimates indicate that the network lacks 162 medical doctors, 1005 midwives and nurses, 132 delivery rooms, and 678 maternity care beds amongst others, with deficits unevenly distributed across facilities.[12] To address these deficits, an estimated budget of United States dollar (US$) 32.9 million would be required from 2025 until 2030, representing an annual increase of about 6% in the total health budget.[12] Therefore, if Burundian policymakers are to fulfil their pledge of achieving the 60% and 50% reductions in maternal and newborn mortality rates by 2030,[10,13] they must rationalise the limited maternal health investments available and tackle inefficiencies within the EmONC healthcare system.

However, with the Burundian total health budget amounting to Burundian francs (BIF) 2,228.7 billion (approximately US$ 112.4 million), which constitutes only 9.6% of the total budget[14] and results in a health expenditure of BIF 25,512 (about US$ 9) per capita, policymakers may struggle to mobilise the US$ 32.9 million necessary for strengthening the EmONC network. This challenge is compounded by the country's persistent health burdens, including outbreaks that overwhelm the health system.[15-19]

Over the past two decades, Burundi has engaged in numerous strategic planning and resource allocation discussions in healthcare, driven by rising priorities and the budgetary pressures, but these efforts have been undermined by an overall economic downturn.[20-22] Achieving the goal of ending preventable maternal mortality (EPMM)[23] and advancing health equity[24,25] requires greater political commitment to health reforms and the strategic redirection of limited resources; commitment that is often lacking in many low- and middle-income countries (LMICs).[26,27] Nonetheless, healthcare systems worldwide regardless of their financing structures and organisation have resource constraints relative to competing priorities, making priority-setting one of the most significant challenges for health policymakers.[28]

To assist Burundian health policymakers in prioritising EmONC investments, we developed in collaboration with stakeholders four workforce investment scenarios that predict the likely costs and maternal health benefits of each proposal over the 2025–2030 horizon. Specifically, we assessed human resource deficits in each EmONC facility against existing workloads, estimated the budgetary requirements to address these deficits under alternative investment scenarios, and forecasted the number of maternal lives each investment scenario is expected to save. Findings from this study will inform policy discussions involving stakeholders and development partners including the United Nations Population Fund (UNFPA), The World Health Organization (WHO), The Japan International Cooperation Agency (JICA), Pathfinder, and various local research and service delivery institutions that support the Burundian maternal health programme.[4]

Methods

Agreeing EmONC workforce policy investment proposals

We developed four scenarios for EmONC workforce investment, as summarised in Table 1, which were discussed and validated with Burundian stakeholders (see Supplemental material S1). The first scenario considers that Burundi may not prioritise any EmONC workforce investments in the near term. The second posits that, if the budget permits, the country may adequately address workforce needs across all EmONC facilities. In the event of budget constraints, two alternative options are proposed: either increasing the workforce by a limited number of personnel, such as adding two midwives in each EmONC facility, or concentrating resources on a select group of 24 priority EmONC facilities comprising 11 BEmONC and 13 CEmONC facilities that would receive a comprehensive package of necessary human resources. These 24 priority facilities were identified in previous research based on criteria such as high delivery workloads, a significant incidence of maternal complications, and a shortage of human resources relative to reported workloads.

Investment scenario	Operational definition	Further comment
Status quo (reference)	No investment	Burundi may not prioritise any EmONC workforce investment
Full package*	Full investment to close HRH needs across all EmONC facilities	Burundi could successfully secure the full budget required to address HRH deficits based on current workloads across all EmONC facilities
Partial package 1	Two additional midwives in each EmONC facility with workforce deficits	If Burundi cannot mobilise the full budget, either it may allocate a small number of health workers such as 2 midwives in each facility facing deficits or concentrate the limited resources to the 24 priority facilities with a comprehensive workforce package.
Partial package 2*	Focused full investment to address workforce needs in 24 priority EmONC facilities	

Table 1. Workforce investment scenarios to strengthen Burundian EmONC facilities. These alternatives were developed with input from study stakeholders (see Supplemental material S1). The costs and benefits of the full and partial workforce investment packages were benchmarked against the status quo scenario. *The estimation of

workforce needs was based on current workloads in 2021 implementing approaches developed in the Workload Indicator for Staffing Needs (WISN) method.

Choice of economic model: the decision tree model

The objective of this study was to provide Burundian decision-makers with insights into the various cost and benefit implications associated with different EmONC workforce investment options (see Table 1). This analysis was effectively conducted using a decision tree model which facilitates the prediction and comparison of costs and impacts related to various investment decisions.[29,30] Our decision tree model consisted of four distinct decision pathways each representing a specific investment option, accompanied by subsequent chance pathways that illustrate the potential events anticipated during childbirth.[30] For example, regardless of whether an investment is made to enhance EmONC workforce capacity, labouring women will invariably face the risk of developing complications, which may result in either survival or mortality. However, the presence of adequately trained delivery care professionals has the potential to improve quality of care (QoC) thereby reducing mortality rates.[31,32] Under typical circumstances, the likelihood of labouring women succumbing to obstetric complications would diminish with the addition of skilled delivery personnel, particularly in contexts characterised by significant workforce shortages.

Pathway outcomes and their probabilities

The ultimate outcomes in our decision pathways are either maternal death or survival. To estimate these outcomes, we utilised records from EmONC facilities in 2021, which included a total of 170,819 deliveries, to derive transition probabilities for the 'status quo' scenario involving obstetric complications and maternal mortality associated with both normal and complicated childbirths. Among these, 37,831 labouring women (probability, Pr = 0.22147) experienced obstetric complications related to abortion, infection, prolonged labour or dystocia, postpartum haemorrhage, and eclamptic disorders. Of these, 2,892 cases resulted in maternal death, leading to an estimated maternal mortality rate of 7,644 deaths per 100,000 obstetric complications (Pr = 0.07644). The data indicated that maternal mortality was lowest following normal childbirths, with 316 deaths recorded among 132,988 normal deliveries (Pr = 0.00238).

We drew on existing evidence to estimate the impact of increasing the number of skilled delivery care providers on maternal mortality rates. A large-scale study published in *The Lancet* in 2021 which examined data from 88 countries estimated that a 95% increase in the number of midwives in LMICs could lead to approximately 14% annual reduction in maternal mortality.[33] Previously in 2015, a similar study condcuted across 58 LMICs indicated that a universal midwivery coverage could result in an estimated 21.33% decrease in maternal mortality each year particularly if sufficient midwives to meet existing workloads are available.[34] We calculated the average predicted impact of a comprehensive midwifery staffing, applying a 17.67% reduction in maternal mortality rate (MMR), with sensitivity analysis limits ranging from 14.0% to 21.33%. Consequently, the probability of a woman succumbing to a maternal complication in an EmONC facility if a full package of midwives is added was calculated as 0.07644 – (0.07644 * 0.1767) = 0.06293. Detailed transition probabilities are presented in Table 2, where branches originating from the same node represent mutually exclusive events that labouring women may experience, with their probabilities summing to 1. For example, if the probability of an obstetric complication is 0.22147, that of a normal delivery is 1 – 0.22147 = 0.77853. Subsequent probabilities of dying or surviving are contingent upon whether the delivery is normal or complicated.

Maternal death probabilities in the event of EmONC facilities receiving two additional midwives are summarised in Table 3. First, we applied the Workload Indicator for Staffing Needs (WISN) methodology[35] to estimate the required activity time in minutes based on workloads and the available capacity which we derived from current staff levels. This allowed us to determine in each facility the prevailing capacity gap. This gap, expressed in minutes, was converted into full-time equivalent (FTE) health workers by dividing the total minutes needed by 80,784 minutes, an estimate representing the annual working minutes per delivery care professional (see details in Box 1). The workforce investment impact for each facility was then calculated as the percentage of this gap that two additional midwives can cover. Using Ngozi hospital for example (i.e., the first line of Table 3), adding two midwives would reduce the workforce gap deficit by 12.53%. Next, we estimated the expected MMR reduction probability in each facility by multiplying the baseline impact of a full workforce package, 17.67% (sensitivity range from 14.0% to 21.33%), by the corresponding proportion of the workforce gap that two midwives can address. For Ngozi hospital, this equates to an estimated MMR reduction of about 2.21% (i.e., 17.67 * 0.1253) with a range from 1.75% to 2.67%. As shown in Table 3, the MMR reduction increases with the size of the workforce gap addressed, capping 17.67% if the addition of two midwives fully addresses the prevailing deficit (i.e., if the workforce gap covered is 1). Finally, these probabilities were averaged across all 104 facilities with deficits, resulting in an overall estimated 8.86% reduction in MMR with corresponding sensitivity range from 7.02% to 10.69%.

Investment scenarios	Code	Probabilities and their ranges	Data source
No investment: status quo			
Normal delivery	*norm-D*	0.77853	These probabilities are based on maternity records from all EmONC facilities for the year 2021
Maternal complication	*compl-D*	0.22147	
Maternal death normal delivery	*death-ND*	0.00238	
Maternal survival normal delivery	*survival-ND*	0.99762	
Maternal death complication	*death-CD*	0.07644	
Maternal survival complication	*survival-CD*	0.92356	
Partial package: adding 2 midwives			
Normal delivery	*norm-D*	0.77853	Adjusted maternal death probabilities reflecting the estimated 8.82% (sensitivity analysis limits from 7.02% to 10.69%) reduction in maternal mortality rate attributable to the addition of two midwives (Table 6.3)
Maternal complication	*compl-D*	0.22147	
Maternal death normal delivery	*death-ND*	0.00217 (0.00221 – 0.00213)	
Maternal survival normal delivery	*survival-ND*	0.99783 (0.99779 – 0.99787)	
Maternal death complication	*death-CD*	0.06967 (0.07107 – 0.06827)	
Maternal survival complication	*survival-CD*	0.93033 (0.92893 – 0.93173)	
Full package: optimal staffing			
Normal delivery	*norm-D*	0.77853	Adjusted maternal death probabilities reflecting the estimated 17.67% (sensitivity analysis limits from 14% to 21.33%) reduction in maternal mortality rate due to an optimal increase in midwifery staffing[33,34,36]
Maternal complication	*compl-D*	0.22147	
Maternal death normal delivery	*death-ND*	0.00196 (0.00205 – 0.00187)	
Maternal survival normal delivery	*survival-ND*	0.99804 (0.99795 – 0.99813)	
Maternal death complication	*death-CD*	0.06293 (0.06574 – 0.06014)	
Maternal survival complication	*survival-CD*	0.93707 (0.93426 – 0.93986)	

Table 2. Pathway probabilities used in the decision-tree model. Under current circumstances, we would reasonably anticipate similar rates of maternal deaths per delivery. Contrary, if two additional midwives are recruited in each EmONC facilities, ceteris paribus, we expect a 10.23 (7.8% to 12.67%) MMR reduction. Furthermore, we would anticipate an even greater MMR reduction i.e., 17.67% (from 14.00% to 21.33%) if facilities were adequately staffed with skilled delivery care providers. These estimates of mortality reductions for each staffing scenario are derived from studies utilising the Lives Saves Tool (LiST) to model the impact of midwifery interventions on mortality in LMICs.

Id	Facility name	Actual workload*	Staffing capacity*	Existing gap*	HRG gap	Workforce impact	Mean impact	Minimum impact	Maximum impact
1	H Ngozi	1,855,219	565,488	1,289,731	15.97	12.53%	2.2136	1.7538	2.6721
2	H Ndora	1,602,631	323,136	1,279,495	15.84	12.63%	2.2313	1.7678	2.6934
3	H Rema	1,374,589	242,352	1,132,237	14.02	14.27%	2.5215	1.9978	3.0437
4	H Musongati	1,441,724	323,136	1,118,588	13.85	14.44%	2.5522	2.0221	3.0809
5	CDS Ntunda	1,243,547	161,568	1,081,979	13.39	14.93%	2.6386	2.0906	3.1851
6	CDS Buraniro	1,142,777	80,784	1,061,993	13.15	15.21%	2.6883	2.1299	3.2451
7	CDS Nyabihanga	1,047,272	80,784	966,488	11.96	16.72%	2.9539	2.3404	3.5657
8	CDS Butezi	1,120,665	161,568	959,097	11.87	16.85%	2.9767	2.3584	3.5932
9	H Muramvya	1,112,185	161,568	950,617	11.77	17.00%	3.0032	2.3795	3.6253
10	H Gahombo	1,273,138	323,136	950,002	11.76	17.01%	3.0052	2.3810	3.6276
11	CDS Gahararo	1,025,184	80,784	944,400	11.69	17.11%	3.0230	2.3951	3.6491
12	CDS Ntega	919,696	-	919,696	11.38	17.57%	3.1042	2.4595	3.7472
13	H Rushubi	1,220,001	323,136	896,865	11.10	18.01%	3.1832	2.5221	3.8425
14	CDS Bukeye I	894,120	-	894,120	11.07	18.07%	3.1930	2.5298	3.8543
15	CDS Giheta	1,050,120	161,568	888,552	11.00	18.18%	3.2130	2.5457	3.8785
16	H Mpanda	1,030,346	161,568	868,778	10.75	18.60%	3.2861	2.6036	3.9668
17	H Giteranyi	983,251	161,568	821,683	10.17	19.66%	3.4745	2.7528	4.1941
18	CDS Muhuta	882,554	80,784	801,770	9.92	20.15%	3.5608	2.8212	4.2983
19	CDS Gatobo	879,230	80,784	798,446	9.88	20.24%	3.5756	2.8329	4.3162
20	CDS Butihinda	958,685	161,568	797,117	9.87	20.27%	3.5815	2.8377	4.3234
21	H Jenda	1,029,558	242,352	787,206	9.74	20.52%	3.6266	2.8734	4.3778
22	CDS Nyamurenza	866,354	80,784	785,570	9.72	20.57%	3.6342	2.8794	4.3869
23	CDS Nyamugari	944,342	161,568	782,774	9.69	20.64%	3.6472	2.8897	4.4026
24	H Rutovu	1,024,417	242,352	782,065	9.68	20.66%	3.6505	2.8923	4.4066
25	CDS Mubuga	859,468	80,784	778,684	9.64	20.75%	3.6663	2.9048	4.4257
26	CDS Nyabitare	833,964	80,784	753,180	9.32	21.45%	3.7905	3.0032	4.5756
27	CDS Munanira	907,181	161,568	745,613	9.23	21.67%	3.8289	3.0337	4.6220
28	H Muyinga	1,041,550	323,136	718,414	8.89	22.49%	3.9739	3.1485	4.7970
29	H Mukenke	1,194,943	484,704	710,239	8.79	22.75%	4.0196	3.1848	4.8522
30	CDS Muriza	869,139	161,568	707,571	8.76	22.83%	4.0348	3.1968	4.8705

31	CDS Musenyi Agrée	862,133	161,568	700,565	8.67	23.06%	4.0751	3.2288	4.9192
32	CDS Murore	771,913	80,784	691,129	8.56	23.38%	4.1308	3.2728	4.9864
33	H Gihanga	1,173,480	484,704	688,776	8.53	23.46%	4.1449	3.2840	5.0034
34	CDS Muyama	848,459	161,568	686,891	8.50	23.52%	4.1563	3.2930	5.0172
35	CDS Karehe	760,927	80,784	680,143	8.42	23.76%	4.1975	3.3257	5.0669
36	H Kayanza	999,227	323,136	676,091	8.37	23.90%	4.2227	3.3456	5.0973
37	CDS Mubanga II	756,009	80,784	675,225	8.36	23.93%	4.2281	3.3499	5.1038
38	H Fota	907,951	242,352	665,599	8.24	24.27%	4.2892	3.3984	5.1777
39	H Gihofi	896,579	242,352	654,227	8.10	24.70%	4.3638	3.4574	5.2677
40	CDS Mutambu	811,218	161,568	649,650	8.04	24.87%	4.3945	3.4818	5.3048
41	CDS Nyagisozi	725,296	80,784	644,512	7.98	25.07%	4.4296	3.5096	5.3471
42	CDS Ruyange	699,981	80,784	619,197	7.66	26.09%	4.6107	3.6530	5.5657
43	H Kinyinya	773,081	161,568	611,513	7.57	26.42%	4.6686	3.6989	5.6356
44	CDS Ruyaga	690,818	80,784	610,034	7.55	26.49%	4.6799	3.7079	5.6493
45	CDS Munzenze	851,337	242,352	608,985	7.54	26.53%	4.6880	3.7143	5.6590
46	H Matana	767,752	161,568	606,184	7.50	26.65%	4.7096	3.7315	5.6851
47	H Rumonge	1,008,197	403,920	604,277	7.48	26.74%	4.7245	3.7432	5.7031
48	CDS Mugendo	588,813	-	588,813	7.29	27.44%	4.8486	3.8415	5.8529
49	H Gitega	909,099	323,136	585,963	7.25	27.57%	4.8722	3.8602	5.8813
50	CDS Bukeye	648,024	80,784	567,240	7.02	28.48%	5.0330	3.9876	6.0755
51	H Butezi	881,771	323,136	558,635	6.92	28.92%	5.1105	4.0491	6.1690
52	H Gashoho	876,153	323,136	553,017	6.85	29.22%	5.1624	4.0902	6.2317
53	CDS Murwi	713,268	161,568	551,700	6.83	29.29%	5.1747	4.1000	6.2466
54	CDS Muramba	631,954	80,784	551,170	6.82	29.31%	5.1797	4.1039	6.2526
55	Clinique agape Rugombo	788,815	242,352	546,463	6.76	29.57%	5.2243	4.1393	6.3065
56	H Kibumbu	692,316	161,568	530,748	6.57	30.44%	5.3790	4.2618	6.4932
57	CDS Maternité Makamba	771,980	242,352	529,628	6.56	30.51%	5.3904	4.2708	6.5069
58	CDS Rusaka	606,459	80,784	525,675	6.51	30.74%	5.4309	4.3029	6.5558
59	CDS Muyange	599,998	80,784	519,214	6.43	31.12%	5.4985	4.3565	6.6374
60	CDS Jene	586,347	80,784	505,563	6.26	31.96%	5.6470	4.4741	6.8166
61	CDS Murago	743,989	242,352	501,637	6.21	32.21%	5.6912	4.5091	6.8700
62	H Kibimba	660,280	161,568	498,712	6.17	32.40%	5.7246	4.5356	6.9103

63	H Bubanza	1,041,469	565,488	475,981	5.89	33.94%	5.9979	4.7522	7.2403
64	CDS Rugabano	548,877	80,784	468,093	5.79	34.52%	6.0990	4.8323	7.3623
65	CDS Musigati	1,193,791	727,056	466,735	5.78	34.62%	6.1168	4.8463	7.3837
66	H Mutoyi	782,523	323,136	459,387	5.69	35.17%	6.2146	4.9238	7.5018
67	CDS Muhanga I	764,320	323,136	441,184	5.46	36.62%	6.4710	5.1270	7.8114
68	CDS Marembo	414,394	-	414,394	5.13	38.99%	6.8894	5.4585	8.3163
69	H Kiganda	728,023	323,136	404,887	5.01	39.90%	7.0511	5.5866	8.5116
70	H Cinquantenaire	799,684	403,920	395,764	4.90	40.82%	7.2137	5.7154	8.7078
71	H Populaire	466,612	80,784	385,828	4.78	41.88%	7.3994	5.8626	8.9321
72	CDS Nyabikere	706,849	323,136	383,713	4.75	42.11%	7.4402	5.8949	8.9813
73	H Mabayi	783,594	403,920	379,674	4.70	42.55%	7.5194	5.9576	9.0769
74	H Musema	459,687	80,784	378,903	4.69	42.64%	7.5347	5.9697	9.0953
75	H Kirundo	776,942	403,920	373,022	4.62	43.31%	7.6535	6.0639	9.2387
76	CDS Murama	453,381	80,784	372,597	4.61	43.36%	7.6622	6.0708	9.2493
77	CDS Ruce	773,620	403,920	369,700	4.58	43.70%	7.7222	6.1183	9.3217
78	H Ntita	761,955	403,920	358,035	4.43	45.13%	7.9738	6.3177	9.6254
79	CDS Kayogoro I	680,213	323,136	357,077	4.42	45.25%	7.9952	6.3346	9.6513
80	CDS Buhinda	513,760	161,568	352,192	4.36	45.87%	8.1061	6.4225	9.7851
81	H Makamba	587,091	242,352	344,739	4.27	46.87%	8.2814	6.5613	9.9967
82	CDS Muyange	497,478	161,568	335,910	4.16	48.10%	8.4990	6.7338	10.2594
83	CDS Gasura	332,477	-	332,477	4.12	48.60%	8.5868	6.8033	10.3654
84	H Buhiga	640,028	323,136	316,892	3.92	50.99%	9.0091	7.1379	10.8751
85	H Kibuye	315,095	-	315,095	3.90	51.28%	9.0605	7.1786	10.9372
86	CDS Ruzo	461,091	161,568	299,523	3.71	53.94%	9.5315	7.5518	11.5058
87	CDS Rwisabi	365,673	80,784	284,889	3.53	56.71%	10.0211	7.9398	12.0968
88	CDS Maramvya	440,198	161,568	278,630	3.45	57.99%	10.2462	8.1181	12.3685
89	CDS Rurama	355,698	80,784	274,914	3.40	58.77%	10.3847	8.2279	12.5357
90	H Rutana	433,114	161,568	271,546	3.36	59.50%	10.5135	8.3299	12.6912
91	CDS Ndava	662,317	403,920	258,397	3.20	62.53%	11.0485	8.7538	13.3370
92	CDS Bugenyuzi	479,501	242,352	237,149	2.94	68.13%	12.0385	9.5381	14.5320
93	H Murore	799,223	565,488	233,735	2.89	69.12%	12.2143	9.6774	14.7442
94	CDS Rugongo	307,513	80,784	226,729	2.81	71.26%	12.5917	9.9765	15.1998

95	CDS Kayanza	307,306	80,784	226,522	2.80	71.33%	12.6032	9.9856	15.2137
96	H Mutaho	708,612	484,704	223,908	2.77	72.16%	12.7504	10.1021	15.3913
97	CDS Kinzanza	428,722	242,352	186,370	2.31	86.69%	15.3185	12.1369	18.4914
98	H Buye	568,518	403,920	164,598	2.04	98.16%	17.3447	13.7423	20.9373
99	H Kiremba	717,072	565,488	151,584	1.88	106.59%	18.8338	14.9221	22.7349
100	CDS Rusamaza	459,499	323,136	136,363	1.69	118.48%	20.9361	16.5877	25.2726
101	H Cibitoke	389,917	323,136	66,781	0.83	241.94%	42.7503	33.8712	51.6052
102	H Nyanza-Lac	383,111	323,136	59,975	0.74	269.39%	47.6016	37.7149	57.4614
103	H Cankuzo	356,454	323,136	33,318	0.41	484.93%	85.6866	67.8898	103.4349
104	CDS Abubef-jabe	265,300	242,352	22,948	0.28	704.06%	124.4076	98.5686	150.1763
105	**H Bururi**	**631,734**	**646,272**	**(14,538)**	**-0.18**	n.a.	n.a.	n.a.	n.a.
106	**H Kabezi**	**683,081**	**727,056**	**(43,975)**	**-0.54**	n.a.	n.a.	n.a.	n.a.
107	**H CPLR**	**1,175,390**	**1,292,544**	**(117,154)**	**-1.45**	n.a.	n.a.	n.a.	n.a.
108	**H Prince Regent Charles**	**168,100**	**323,136**	**(155,036)**	**-1.92**	n.a.	n.a.	n.a.	n.a.
109	**H Militaire Kamenge**	**586,405**	**888,624**	**(302,219)**	**-3.74**	n.a.	n.a.	n.a.	n.a.
110	**H Van Normann**	**679,772**	**1,130,976**	**(451,204)**	**-5.59**	n.a.	n.a.	n.a.	n.a.
111	**H Roi Khaled**	**798,687**	**1,292,544**	**(493,857)**	**-6.11**	n.a.	n.a.	n.a.	n.a.
Total worker deficit					**726**	***Probabilities***	**8.86**	**7.02**	**10.69**
Total worker surplus					**20**				

Table 3 Estimation of the impact of two additional midwives on MMR reduction across facilities with workforce deficits. The first three columns marked with a star (*) display time in minutes representing the required activity time based on standards, the available capacity based on current HRH, and the existing capacity gap. The gap is converted into full-time equivalent health workers by dividing the total minutes needed by 80,784 minutes (i.e., annual working minutes per professional, see Box 1). The workforce impact is then calculated as the percentage of this gap that two additional midwives can cover. For instance, adding two midwives in Ngozi hospital (line 1) reduces the workforce gap by 12.53%. The expected MMR reduction probabilities are derived by multiplying the baseline impact of 17.67% (range from 14.0% to 21.3%) by the proportion of the workforce gap addressed. For Ngozi hospital for instance, which has a deficit of about 16 health workers, this corresponds to an estimated MMR reduction of approximately 2.21% (range from 1.75% to 2.67%). The MMR reduction increases with the workforce gap, reaching 17.6% (14.0%, 21.33%) if the workforce addition fully addresses deficit. These probabilities are averaged across all 104 facilities with deficits and are used to estimate the overall MMR reduction if two midwives are added to each facility. Facilities with a workforce surplus (i.e., total surplus of 20 health workers across 7 facilities) are in bold and excluded from investment considerations.

The workload approach to estimate staffing needs

The comprehensive workforce package designed for all EmONC facilities, along with that targeted at the 24 priority facilities, correspond to the amounts of skilled delivery workers required to address current workloads in each concerned facility. To estimate staffing needs, we analysed maternal and neonatal care records from each of these facility, specifically focusing on the total number of deliveries, both instrumental and non-instrumental and the number of mothers and newborns who received specialised care for complications such as postpartum haemorrhage, uterine rapture, caesarean sections, severe preeclampsia and eclampsia, abortion, and neonatal asphyxia; conditions that are among the most prevalent and life-threatening.[37-42]

These records were used to estimate the prevailing yearly workloads in minutes using the activity duration approach outlined in the WISN methodology.[35] Subsequently, we summarised the literature on maternal and newborn care activity durations from studies employing the WISN approach, including a multicounty study conducted in 12 African countries[43] as well as individual studies conducted in Burkina Faso,[44] Côte d'Ivoire, Niger, and Kenya,[45] Brazil,[46] and Iran.[47] Estimates indicate that a normal childbirth, both instrumental and non-instrumental, would require an average of 219 and 190 minutes of skill-mix labour respectively. Comprehensive care for a caesarean section is estimated to take 132 minutes, while the management of post-partum haemorrhage and uterine rupture as well as severe preeclampsia and eclampsia each necessitates approximately 196 minutes of skilled labour. In terms of newborn care, a professional nurse or midwife typically spends an average of 28 minutes providing the full healthcare package associated with immediate newborn care and about 15 minutes performing neonatal resuscitation. Additional activities reported in Burundian EmONC facilities include care following incomplete abortions, which we estimate to require approximately 131 minutes of skilled labour, and the postpartum counselling to educate mothers on newborn feeding guidelines and to schedule postnatal appointments and family planning, activities a professional nurse or midwife can complete in about 22 minutes (Supplemental material S2). The goal was to compare workloads with available workforce capacity deriving staffing deficits. To achieve this, we calculated annual workload estimates in minutes for each EmONC facility by multiplying the total number of activities by their respective average durations, subsequently aggregating these durations across activities (see Equation 1). We then estimated the workforce capacity by determining the total number of minutes each skilled delivery personnel is expected to work in a year considering that Burundi observes 17 public holidays and that all employees are entitled to 20 days of leave. Additionally, we factored other possible reasons of absenteeism as explained in Equation 2 of Box 1. Furthermore, based on existing evidence we assumed that approximately 15% of daily working time is allocated for authorised breaks (e.g., lunch) and personal matters (e.g., social communications), as well as possible administrative tasks, fatigue-related inactivity, and delays at work.[47] Consequently, a typical health worker in Burundi is expected to formally work 80,784 minutes in a year (see details in Box 1).

Based on the expected time it would take to provide care to the numbers and case-mix of women attending a facility and subtracting the working time available at a facility, based on its workforce complement, we were able to calculate a required working time deficit as a measure of 'overwork'. The working time deficit for a facility can also then be used to calculate its additional workforce requirement as explained in Table 3.

Box 1. Equations and assumptions used to estimate workloads and workforce capacity

$$\lambda_j = \sum_{i=n} X_{ij} \times \delta_i$$

Equation 1, where λ_j is the workload in minutes for facility j, X_{ij} corresponds to the total activities in facility j with i representing the types of activities e.g., normal delivery and X is the number of i activities, and δ_i is the average activity duration for activity i (see Supplemental material S2). n is the number of activity types in each facility.

$$\gamma_j = \alpha \sum_{i=3}^{i=1} n_{ij} \times \mu_i$$

Equation 2, where γ_j is the expected total working time in facility j, n_{ij} corresponds to the total delivery care professionals available in facility j with i representing each provider type i.e., doctor, midwife, nurse. μ_i is the total time provider i is expected to work in a year. α = 0.15 is the time discount factor to account for time not spent on providing care such as lunch and breaks.

Fo For instance, Ngozi hospital which has the largest workforce deficit reported performing 2182 normal deliveries and 783 instrumental deliveries, along with 1035 cases of prolonged labour and 772 caesarean sections. Additionally, the hospital managed 14 cases of uterine rupture, 250 mothers with postpartum haemorrhage, and 15 women with preeclampsia and eclampsia. It also treated 30 cases of infected or septic childbirth, handled 1165 indirect and other maternal complications, and managed 120 newborn infections. Furthermore, 126 newborns received resuscitation care along with 460 low birth babies who received treatment. These workloads amounted to approximately 1,843,339 minutes as detailed below:

$$\begin{aligned} Labour \ = \ & (3737\ deliveries \text{ x } 147) + (2182\ normal\ deliveries \text{ x } 219) + (783\ instrumental\ deliveries \text{ x } 190) \\ & + (772\ c-sections \text{ x } 132) + (2509\ complications \text{ x } 196) + (14\ abortions \text{ x } 131) \\ & + (126\ newborn\ resuscitations \text{ x } 15) \\ & + (580\ low\ birth\ weights\ and\ infected\ newborns \text{ x } 80) \end{aligned}$$

On the other hand, there are 7 delivery care providers in Ngozi hospital assigned to maternity which corresponds to 565,488 person-minutes in a year as given by the calculus below:

$$Capacity \ = \ 7\ providers \text{ x } 198\ days \text{ x } 8\ hours \text{ x } 60\ minutes \text{ x } 0.85$$

In the context of Burundi we estimated that healthcare providers work 198 days per calendar year. Indeed, government staff typically work five days a week resulting in a total of 260 days (5 days x 52 weeks). However, this figure was adjusted for 17 public holidays, 20 days of leave, an estimated 15 days of sick leave, and an additional 10 days of absenteeism and other personal leave. Thus, the effective working days are calculated as 260 days – 62 days yielding a total of 198 working days per year.

Data and sensitivity analyses

The costs associated with each workforce investment option reflect the total government budgetary expenditure over a five-year period. Details regarding cost data collection and the costing methodology are outlined in our previous report.[12] This includes government salaries adjusted for an annual 3% growth rate and the costs associated with the recommended onset and biennial EmONC training. The five-year policy perspective spanning from 2025 to 2030 was selected to align with Burundi's medium-term planning preferences and coincides with the remaining timeframe of the Sustainable Development Goals (SDGs) agenda[48] and The Survive, Thrive, and Transform agenda.[49] For better interpretation, health outcomes (i.e., maternal deaths) were calculated by multiplying pathway probabilities by 100,000 deliveries (MMR). Additionally, for each investment option relative to the status quo we estimated the expected number of maternal lives saved per 100,000 deliveries allowing us to compute the cost per maternal life saved. To address uncertainties in the parameters and assess the robustness of our estimates, we conducted a sensitivity analysis using the upper and lower limits of the impact of each midwifery intervention option on maternal mortality (Table 2).

Results

Human resources needs and budgetary implications

Figure 1 illustrates the workload-based time deficits in minutes per year, as well as the anticipated impact of adding two midwives to each EmONC facility. One BEmONC lacked maternal and newborn records and was excluded from analysis. Our explorations revealed that only 7 out of 111 EmONC facilities all large hospitals meet the workload staffing index based on the WISN criteria. Among these five tertiary hospitals located in Bujumbura capital city have between 1 and 6 workers more delivery care professionals than required totalling 20 excess health workers (see Table 3). Conversely, Figure 1 and Table 3 show that 8 BEmONC and 9 CEmONC facilities are short by more than 10 additional skilled delivery providers each. Moreover, 52 facilities predominantly BEmONC (n = 33) require between 5 and 10 additional workers, while 35 facilities comprising 17 BEmONC and 18

CEmONC lack between 1 and 5 health workers. As illustrated in Figure 1, adding two midwives to each facility would address the workforce deficit of 4 additional facilities but this partial investment does not sufficiently resolve the broader workforce shortages faced by many others.

Using the WISN approach, we estimated a total workforce deficit across the EmONC network of 58,649,184 minutes equivalent to approximately 726 skilled delivery care providers (Table 3), which we express in midwives. Furthermore, this approach revealed a workforce deficit of 17,287,776 minutes within the 24 priority facilities which translates to nearly 214 midwives. Investment scenario 2 involves fully addressing the estimated workforce gap in 104 facilities with shortages, excluding any reallocation to those diagnosed with excess workforce. This scenario requires Burundi to commit approximately BIF 32,494,340,294.22 (US$ 11,092,717.23) to cover the salaries of 726 midwives and to provide these additional staff with biennial EmONC training over a period of five years.

Alternatively, the third scenario proposes adding two midwives to 104 facilities excluding the 7 facilities with excess workers. This option would incur an estimated cost of approximately BIF 9,309,673,252.34 (US$ 3,178.078.77) to cover the salaries and EmONC training expenses of the projected 208 newly recruited midwives over five years. The final scenario focuses on the 24 priority facilities, requiring 214 midwives to address their workforce deficits, which amounts to an estimated budget of BIF 9,578,221,519.23 (US$ 3,269,754.11) over five years.

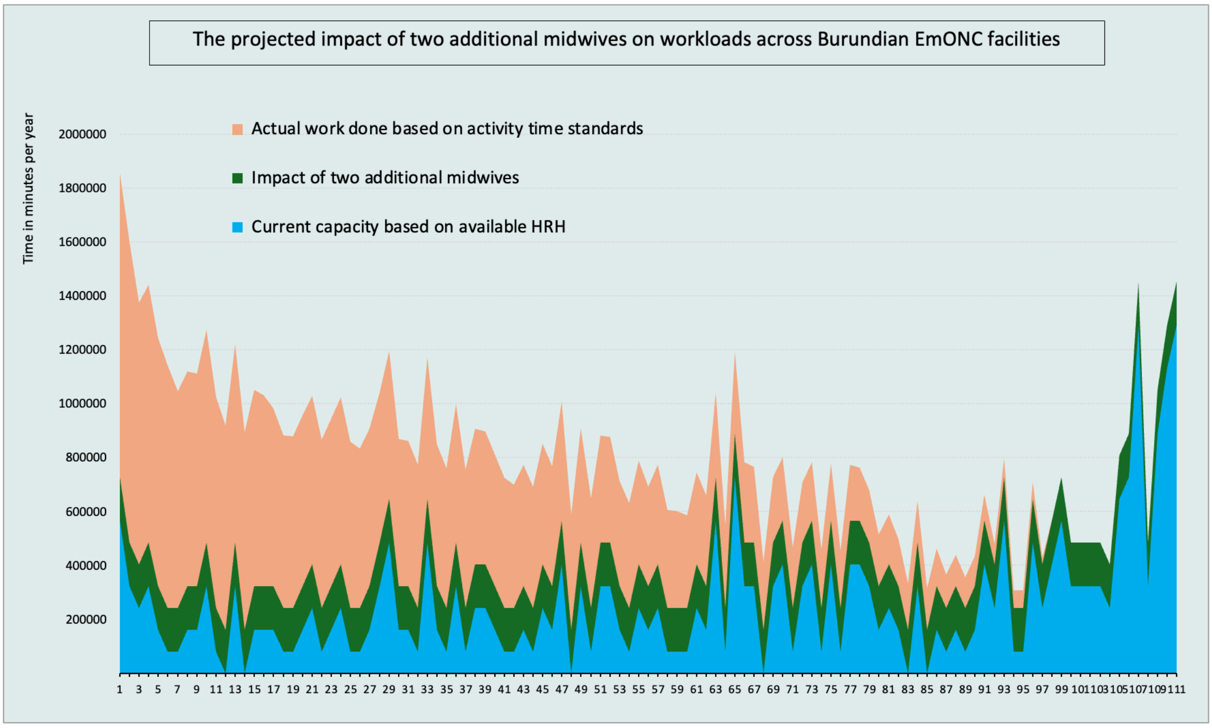

Figure 1. Workforce deficits by facility. This figure compares the current workforce capacity in minutes against prevailing workloads to highlight workforce gaps in each facility. Additionally, it illustrates the potential impact of two additional midwives on narrowing these existing workforce deficits.

Predicted maternal health gains

Under current circumstances, the status quo branch in Figure 2 indicates that approximately 1,878 women per 100,000 deliveries are expected to die with 90% of these maternal deaths attributed to obstetric complications. Consequently, if Burundi does not make an EmONC workforce investment in the near term, we anticipate approximately 3,208 maternal deaths among the estimated 170,819 deliveries to occur annually across the 112 EmONC facilities.

Records indicate that the 104 facilities experiencing workforce shortages performed a total of 160,384 deliveries in 2021; accounting for approximately 94% of all deliveries in EmONC facilities. If

Burundi commits the necessary budget to fully address workforce deficits in these 104 facilities, such an optimal increase in midwifery staffing is projected to reduce MMR by 17.67% annually, with sensitivity limits ranging from 14% to 21.33% (see Table 2). We see in Figure 2 that under these optimal workforce conditions maternal mortality is expected to fall from 1,878 to approximately 1,546 deaths per 100,000 deliveries (with a range from 1,478 to 1,615 maternal deaths) resulting in an estimated 532 maternal lives saved annually from the total 160,384 deliveries.

In the context of budget constraints, one policy scenario advances increasing the workforce by adding two midwives to each of the 104 facilities that are facing staff shortages. With the addition of two midwives in each facility and an expected reduction in maternal mortality of 8.86% (with sensitivity limits of 7.02% to 10.69%), we anticipate approximately 1,712 (from 1,677 to 1,746) maternal deaths per 100,000 deliveries; translating to an estimated total of 2,745 (from 2,690 to 2,801) maternal deaths for the 160,384 deliveries occurring annually in these facilities. This investment scenario is therefore projected to save approximately 267 maternal lives annually (sensitivity ranges of 211 to 322 maternal lives) across the 104 facilities.

Under the same budgetary challenges, another policy option would be to focus on the 24 priority EmONC facilities with a comprehensive workforce package. These facilities performed 49,134 deliveries in 2021, representing nearly 29% of all deliveries across the EmONC network. Under current conditions, it is estimated that 923 women die during childbirth annually in these priority facilities. However, if they are equipped with the necessary human resources to address prevailing maternity workloads, the maternal death toll is projected to decline from 923 to 760 annual deaths with sensitivity limits ranging from 726 to 794 maternal deaths. This investment would result in an estimated annual savings of 163 maternal lives (with a range from 129 to 197).

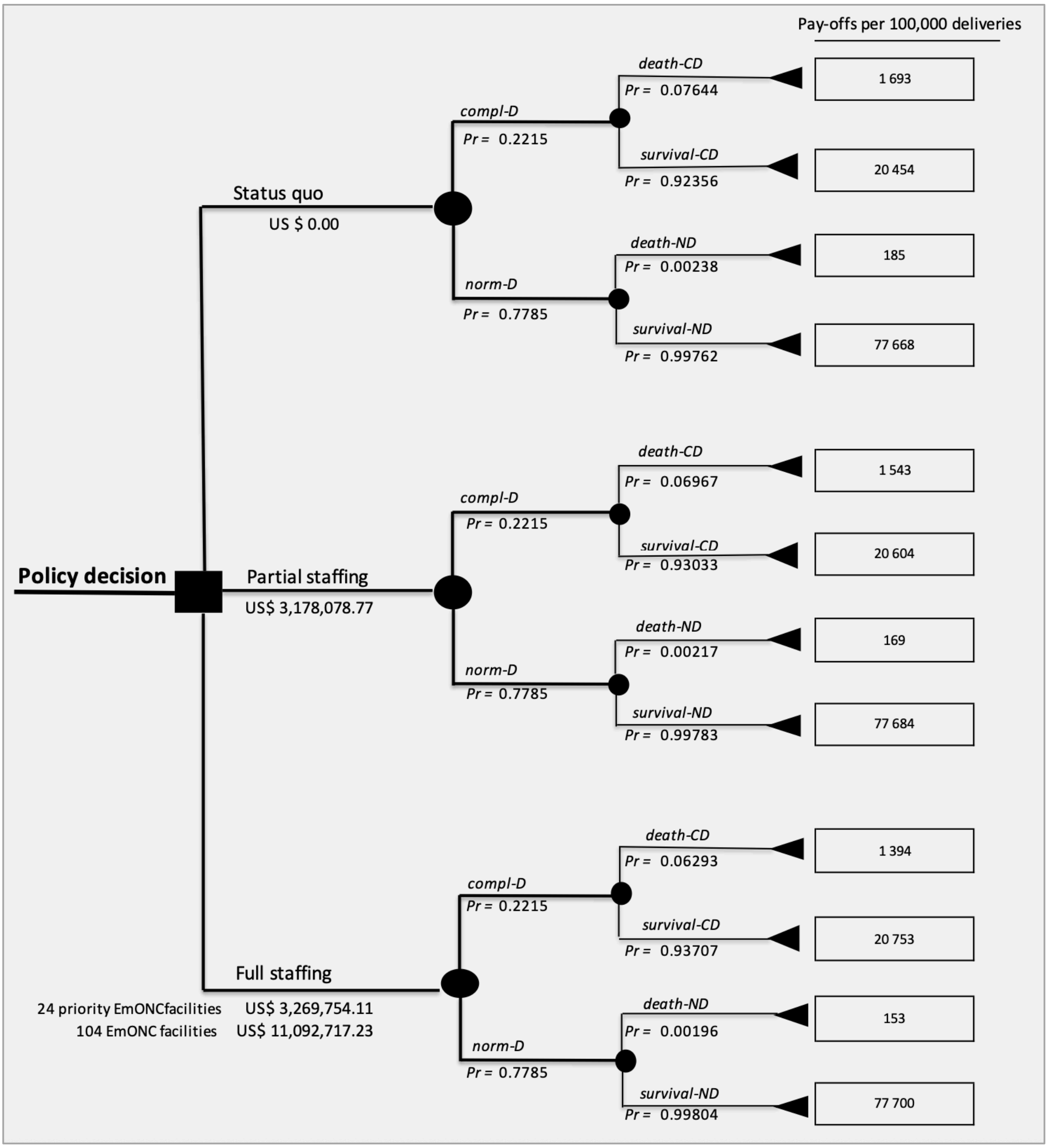

Figure 2. **Decision Tree predicting the outcomes of different EmONC investment options**. This decision tree features three branches each representing an investment decision with the full staffing branch representing both an investment targeting the 24 priority facilities and the 104 EmONC facilities. The number of maternal deaths and survivals is adjusted per 100,000 deliveries. Probabilities and denoted as *Pr*; *norm-D* refers to "normal deliveries" while *compl-D indicates* "complicated deliveries". Furthermore, *death-ND* represents "maternal death following a normal delivery"; *death-CD* signifies "maternal death following an obstetric complication", *survival-ND* denotes "maternal survival following a normal delivery"; and *survival-CD* indicates "maternal survival following an obstetric complication".

■ is the decision node; ● are chance nodes; ◀ correspond to terminal nodes.

The results of the cost-benefit analysis are summarised in Table 4. The budgets in US dollars of each investment alternative are annualised by dividing each total investment by five years. If Burundi does not invest in EmONC to address the workforce deficits across the 104 facilities, it is estimated that 3,012 out of 160,384 labouring mothers will die annually. In comparison, the analysis indicates that a partial investment of two additional midwives in each facility is more cost effective with an average expenditure of US$ 2,380.58 (between US$ 1,973.96 and US$ 3,380.58) spent for each maternal death averted. In contrast, implementing any of the full workforce packages would be significantly more expensive costing nearly double the amount required to save a maternal life compared to adding two midwives across facilities with staff shortages. For instance, averting one maternal death is estimated to cost on average US$ 4,170.19 (between US$ 3,455.68 and US$ 5,269.70) if all 104 facilities are equipped with a comprehensive workforce package to address existing workloads. If the comprehensive workforce package is directed solely to the 24 priority EmONC facilities, the average cost per maternal death averted rises to US$ 4.018.46 (between US$ 3,319.55 and US$ 4.018.46).

	Maternal death estimates per 100,000 deliveries	Annual maternal deaths	Incremental maternal lives saved annually	Cost in US$ per maternal life saved
Status quo (reference: US$ 0.00)	**1 878**	**3 012***	—	—
Partial investment (US$ 635,615.75)				
Average reduction estimates	1 712	2 745	267	**2,380.58**
Lowest reduction estimates	1 746	2 801	211	**3,012.40**
Highest reduction estimates	1 677	2 690	322	**1,973.96**
Full package 104 facilities (US$ 2,218,543.45)				
Average reduction estimates	1 546	2 480	532	4,170.19
Lowest reduction estimates	1 615	2 591	421	5,269.70
Highest reduction estimates	1 478	2 370	642	3,455.68
Full package 24 priority facilities (US$ 653,950.82)		**923****		
Average reduction estimates	1 546	760	163	4.018.46
Lowest reduction estimates	1 615	794	129	5,069.39
Highest reduction estimates	1 478	726	197	3,319.55

Table 4. Cost estimates in US$ per maternal life saved. The budgets in US$ are annualised by dividing each total investment by five years. Maternal deaths per 100,000 deliveries reflect the total deaths resulting from both normal and complicated childbirths as presented in the Decision Tree. These estimates were adjusted to align with the actual annual deliveries totalling 160,384 across the 104 EmONC facilities and 49,134 in the 24 priority EmONC facilities. The cost in US dollar per maternal life saved was calculated by dividing the annual budget by the corresponding annual incremental lives saved. The average maternal reduction estimates are 10.23% for the partial package and 17.67% for the full packages. The lowest reductions estimates are 7.80% and 14.00% for the partial and the full packages, respectively, while the highest reduction estimates are 12.67% and 21.33% for the partial and full workforce packages; respectively. *Annual maternal deaths in the 104 facilities and **annual maternal deaths in the 24 priority facilities.

Discussion

This paper employs decision tree methodologies to predict the costs and benefits associated with four workforce investment scenarios targeting Burundian EmONC facilities. The primary objective is to assist Burundian health policymakers in prioritising EmONC investments amidst limited resources and competing health priorities[15-19,50-53] thereby rationalising resource allocation and addressing inefficiencies within the EmONC healthcare system. This is particularly critical given that Burundi allocates approximately US$ 112.4 million to its health sector, resulting in a health expenditure of about US$ 9 per capita, while an estimated US$ 32.9 million is needed to address capacity deficits across the 112 EmONC facilities over five years representing an annual increase of roughly 6% in the total health budget.[12]

The first scenario posits that Burundi does not prioritise any EmONC investment. The second assumes budget availability and suggests a comprehensive investment to address workforce deficits. The third and fourth scenarios address budget constraints, offering two alternatives: either increasing the workforce by adding two midwives to each EmONC facility or focusing resources on a select group of 24 priority EmONC facilities comprising 11 BEmONC and 13 CEmONC facilities that would receive a comprehensive package of necessary human resources. These 24 priority facilities were identified based on criteria such as high delivery workloads, a significant incidence of maternal complications, and a shortage of human resources relative to reported workloads.

Among the 111 EmONC facilities with data, five tertiary hospitals located in Bujumbura and two district hospitals have enough skilled delivery care professionals needed to meet current delivery workloads based on the WISN criteria. The remaining 104 facilities exhibit variable workforce shortages with 17 facilities lacking more than 10 skilled delivery providers each and 52 facilities needing between 5 and 10 providers. Overall, there is a deficit of approximately 726 skilled delivery care providers across the 104 facilities and 214 providers in the 24 priority facilities.

If Burundi successfully mobilises sufficient funding to comprehensively address these workforce deficits, an average budget of approximately US$ 11.1 million will be required to cover the salaries and EmONC training expenses for the 726 new staff over five years (about US$ 2.22 million annually). This optimal investment is projected to save 532 maternal lives annually on average from the total 160,384 deliveries taking place in these facilities. In the context of budget constraints, a workforce investment directed at the 24 priority EmONC facilities would cost approximately US$ 3.27 million for five years, equivalent to US$ 0.65 million annually, and is expected to avert an estimated 163 maternal deaths among the 49,134 mothers delivering in those priority facility each year. Alternatively, investing in two midwives across the 104 facilities with workforce shortages is expected to save 267 maternal lives annually among the 160,384 deliveries at an expense of approximately US$ 3.18 million over five years (i.e., US$ 0.64 million annually).

If Burundi fails to invest in its EmONC workforce in the near future, nearly 3,012 mothers among 160,384 deliveries will continue to die annually across the 104 EmONC facilities indicating an unlikely progress towards achieving the 60% and 50% reductions in maternal and newborn mortality rates by 2030.[10,13] Importantly, EmONC facilities account for less than 8% of health facilities nationwide and perform only one third of the 85% of deliveries occurring in health facilities[3] and manage nearly two-thirds of obstetric complications.[4,5] Given that an estimated 1,878 mothers die per 100,000 deliveries within these specialised maternity hubs which have received policy attention over the past eight years, it is likely that mortality rates are even higher in non-EmONC facilities which over the past decade lost policy focus even though they continue to handle two-thirds of deliveries alongside 33% of complications. Indeed, research has consistently shown that maternal mortality attributable to obstetric complications is highly likely in under-resourced health settings.[54-58]

Our results indicate that a partial investment of adding two midwives to each of the 104 facilities with human resources deficits is more cost-effective than comprehensive workforce packages. With this investment, Burundi is expected to spend approximately US$ 2,380.58 (between US$ 1,973.96 and US$ 3,012.40) for each maternal death averted whereas implementing any comprehensive workforce package would double this expenditure per maternal life gained.

These policy options will be discussed with stakeholders in Burundi, focusing on the likely available or mobilizable health budget for immediate investment. If Burundi can successfully mobilise more than the US$ 3.18 million needed to recruit two midwives in each EmONC facility facing human resources deficits, we will explore how any supplementary budget could be effectively invested to address previously identified non-staff issues.[12]

We acknowledge three major limitations in this study. First, although transition parameters were derived from empirical evidence on the impact of midwifery interventions on maternal mortality reductions in LMICs and sensitivity analyses conducted, there remains a possibility that these parameters may misestimate the actual impact of midwifery interventions in Burundi's context. Second, increasing human resources will only be effective if the supporting infrastructure such as equipment, laboratory and imaging, drugs, and supplies is in place although this analysis focused on workforce and did not account for those important contributors. Finally, if Burundi's maternity records used in this analysis are inaccurate, this may affect the estimation of workforce deficits causing therefore a misallocation of resources where they are not most needed.

Conclusion

We have demonstrated the potential costs and benefits associated with partial and comprehensive EmONC workforce investment scenarios in the context of Burundi. While the parameters used in this modelling study are based on global empirical evidence and not specifically tailored to Burundi, we believe the findings, particularly the cost and benefits estimates, are relevant and can effectively guide Burundian health policymakers in prioritising EmONC workforce investments in the near future. Results proved that a partial investment of two additional midwives in each EmONC facility facing human resources deficits is more cost-effective than any comprehensive midwifery packages. The policy implication of this finding is the potential for significant budget savings which could be redirected to enhance other non-human resource components of EmONC facilities.

Declarations

Acknowledgements

We acknowledge the members of the study stakeholder committee in Burundi (Supplemental material S1) and individual experts namely Nadine Misago, Kelly Joelle Gatore Sinigirira, Jean De Dieu Nkurunziza, Abdu Adamu, Elvis Omondi Wambiya, Zacharie Ndizeye, Sandra Nkurunziza, Jean Paul Ndayizeye, Salvator Harerimana, Moise Muzigaba, Jalemba Aluvaala, and Ambrose Agweyu who shared expert opinion pertaining to either this study or the umbrella study that provided datasets used to perform these particular analyses.

Declaration of Interest statement

The authors declare no conflicts of interest.

Availability of data and files

This study used datasets from the main EmONC facility survey and routine monitoring data which are not publicly available as primarily owned by the Burundian Ministry of Health (MoH) and are bound by a strong data sharing policy which does not permit authors to share them. However, these data can be obtained by sending a reasonable request to the reproductive, maternal, newborn, child, and adolescent's health programme of the Burundian MoH. The corresponding author can share STATA command files upon request.

Authors' contributions

DH conceptualized and wrote the study protocol, engaged policy makers and stakeholders in Burundi, sought ethics approvals and the World Health Organization's (WHO) funding for fieldwork, curated and analysed data, and wrote the first and final drafts of the manuscript. AL, CN, and ME contributed substantially to the study conceptualization, guided data analysis, and reviewed the drafts manuscript. JBN, AN, AB, JN, ESDN, and SB reviewed the study protocol and helped to coordinate stakeholder discussions. PN† contributed to the study conceptualisation but died during the course of the study conduct. All authors read and approved the final manuscript.

Ethics approval and consent to participate

This study was approved by the Human Research Ethics Committee of the Faculty of Medicine of the University of Burundi (Ethics certificate FM/CE/01/M/2022) and the University of Oxford's Tropical

Research Ethics Committee (OxTREC approval reference: 516-22). Participation was voluntary and all participants signed a written informed consent form.

Funding
Data collection activities were funded by WHO country office in Burundi. Mike English contributed expertise thanks to his Wellcome Trust Senior Research Fellowship (#207522). None of these funders had a role in data analysis and reporting or in deciding to publish this manuscript. The authors had the final responsibility to decide to submit the manuscript for publication.

Consent for publication
Not applicable.

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Supplementary material S1. List of study stakeholders

Names	Position and institution
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2. Dr Oscar Ntihabose	Director General Health Services, MoH
3. Dr Ananie Ndacayisaba	Director of the RMNCAH Programme, MoH
4. Dr Zacharie Kubwimana	Director of Programme, MoH
5. Dr Theophile Bigayi	Deputy Director RMNCAH Programme, MoH
6. Prof Sylvestre Bazikamwe*	Professor of Gynecology and Obstetrics , University of Burundi
7. Dr Jeanine Ndayisenga**	Paediatrician Research Fellow, National Institute of Public Health
8. Dr Yolande Magonyagi	National Programme Officer SRH, United Nations Population Fund (UNFPA)
9. Dr Eugenie Siga Diane Niane	Programme Officer RMNCAH, World Health Organization (WHO)
10. Dr Brigitte Ndelema	National Programme Officer RMNCAH, WHO
11. Dr Aristide Bishinga	EmONC Specialist, Japan International Cooperation Agency (JICA)
12. Dr Dorothee Ntakirutimana	Health Specialist, United Nations Children's Fund (UNICEF)
13. Dr Josiane Nijimbere	Scientist RMNCAH Programme, MoH
14. Dr Jean Claude Mugisha	Scientist RMNCAH Programme, MoH
15. Dr Innocent Nkurunziza	Secretary, MoH
16. Dr Anaclet Nahayo	Director of HIS, MoH
17. Olivier Gahungere, Mr	Statistician, RMNCAH Programme, MoH
18. Thierry Nzeyimana, Mr	Monitoring and Evaluation, RMNCAH Programme, MoH
19. Daniel Habonimana, Mr	Monitoring and Evaluation, RMNCAH Programme, MoH
20. Souverienne Bucumi, Mrs	Monitoring and Evaluation, RMNCAH Programme, MoH
21. Rose Simone Ndayiziga, Mrs	Scientist, National HIV/AIDS programme, MoH
22. Nadine Muhimbare, Ms.	Cabinet Secretary, MoH
23. Therence Nduwarugira, Mr	Scientist, UNFPA

*He also represents the Burundian Association of Gynaecology-Obstetricians (AGOB)
**She also represents the Burundian Association of Neonatology (ABUNE)

Supplemental material S2. Maternal and newborn care activity durations in minutes

Publication	Delivery care Professional	Type of activity (care)	Activity duration (min)
De Menezes et al., 2022 (Brazil)[46]	Medical specialists	Care for normal deliveries without instrumentation	152
		Care for normal deliveries with instrumentation	190
		Care for caesarean deliveries	175
		Manual vacuum aspiration (MVA)	124
		Uterine curettage	138
		Routine examination of patients in pre-labour, labour, and postpartum beds	147
		Care for severe patients	196
Tabatabaee and Daghighbin, 2020 (Iran)[47]	Midwives	Childbirth (labour and delivery care)	310
		Recovery after caesarean	60
		Newborn cardiopulmonary resuscitation (CPR)	15
		Recovery and Postpartum Care	80
Ly et al., 2014 (Burkina Faso)[44]	Midwives	Delivery	173
		Caesarean	16
		Family planning consultation	11
		Patient care	13
		Completing admin/patient records	15
		Manual vacuum aspiration (MVA)	30
		Family planning counselling	19
		Pre-caesarean care	74
Kpebo et al., 2022 (Cote d'Ivoire)[45]	Nurses and Midwives	Delivery care	176
		Postnatal care	24
		Family planning consultation	23
Kpebo et al., 2022 (Burkina Faso)	Nurses and Midwives	Delivery	171
		Postnatal care	26
		Family planning consultation	24
Kpebo et al., 2022 (Niger)[45]	Nurses and Midwives	Delivery care	242
		Postnatal care	28
		Family planning consultation	24
Kunjumen et al., 2022 (Kenya)[45]	Nurse and Clinical Officer	Admission of pregnant woman	45
		Labour management	294
		Normal delivery	40
		Immediate newborn care	20
		Immediate maternal care	15
		Newborn care after 24h of birth	40
		Discharge of mother and baby	20
Ahmat et al., 2022 (12 countries: WHO African region)[43]	Midwives	Admission of pregnant woman	40
		Postnatal care	31
		Normal delivery	196

Supplemental material S2 summarises the findings from a literature search on the standards and durations of maternal and newborn care activities, focusing on published research in low- and middle-income countries (LMICs) particularly within the African context. The 14 African countries on which these estimates draw care activities include Benin, Botswana, Burkina Faso, Chad, Cote d'Ivoire, Ghana, Kenya, Liberia, Malawi, Namibia, Niger, Nigeria, South Africa, and Zimbabwe.