

Examining and addressing the structural and workforce challenges facing Burundi's Emergency Obstetric and Neonatal Care (EmONC) Network

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A thesis submitted to the Nuffield Department of Clinical Medicine, Medical Sciences Division, University of Oxford for the fulfilment of the Degree of Doctor of Philosophy.

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DECLARATION

I, Desire Habonimana, declare that this doctoral research work was carried out by me under the supervision of Mike English, Professor of International Child Health; Catia Nicodemo, Associate Professor in Health Economics; and Attakrit Leckcivilize, Postdoctoral Scientist in Health Economics all based at Oxford University. Except where explicitly stated otherwise in the report, this thesis was entirely composed by myself and the findings presented herein are the result of my work and include nothing which is the outcome of work done in collaboration. The contents are original, have not been and will not be submitted, either in part or in full, for the award of any other degree or diploma in this or any other institute or university. I also declare that I have taken care in all respects to honour the intellectual property right by acknowledging the contribution of others, wherever relevant, for using them in this work.

Oxford, United Kingdom

June, 2025.



Desire Habonimana

DEDICATION

I humbly dedicate this degree of Doctor of Philosophy (DPhil, PhD) to the Lord almighty who has made it possible for me to come this far in education. A special feeling of gratitude to my beloved wife, Petronie Nyawenda; and children; Perry Dylann Habonimana, Alivia Skylar Habonimana, Ethan Pedro Habonimana, and Asta Bithiah Habonimana for your unconditional love, your support, and your patience. My father, late mother, late brother and sisters, brothers and sisters, you all have never left my side, physically or emotionally, and are very special to me. Through thick and thin, you have provided me all the support to make this level of my education come to pass.

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I also dedicate this thesis to the Burundian community in the United Kingdom, the 2016 MSc Implementation Science fellows from the University of the Witwatersrand (Wits) of Johannesburg, and many friends who have supported me in many ways. I will always value all you have done to me.

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It is due to the above collective assistance that this doctoral training was made possible!

Abstract

In 2015, Burundi committed to reducing maternal mortality by 60% (from 334 to 140 maternal deaths per 100,000 livebirths) and halving neonatal mortality (from 23 to 12 newborn deaths per 1,000 livebirths) by 2030. To achieve this, the country established in 2017 a "maternity network" comprising 112 emergency obstetric and neonatal care (EmONC) facilities distributed nationally, supported by development partners and policies to enhance their capacity. Despite these political and financial efforts, maternal and newborn death rates remained persistently high, compounded by the ongoing challenges in resource allocation. I used multiple-methods spanning document review, clinical EmONC vignettes, facility surveys, stakeholder engagement, and employed various statistical approaches to identify structural and workforce challenges and to develop efficient, equitable workforce investment proposals that could improve EmONC facility readiness.

Initial explorations revealed that the classification of EmONC facilities into basic (BEmONC) and comprehensive (CEmONC) levels does not align with expected standards, as some BEmONC facilities perform CEmONC 'signal functions' and manage more deliveries and complications than hospitals. Using normative and expert resource thresholds, I identified deficits of approximately 162 doctors, 1,005 midwives and nurses, 132 delivery rooms, and 678 maternity beds, amongst others. Addressing these gaps would require United States dollar (US$) 32.9 million over five years, representing a 6% annual increase in health spending. A prioritisation framework identified 11 BEmONC and 13 CEmONC facilities, responsible for 30% of deliveries and 35% of complications but housing only 15% of available human resources, highlighting critical investment targets in the face of limited resources. Applying the Workload Indicator for Staffing Needs (WISN) methodology, I developed four workforce investment proposals, validated with stakeholders, and used a decision tree model to compare the costs and expected benefits. Results suggest that adding two midwives in each facility is more cost-effective, at approximately US$ 2,381 per maternal life saved, nearly half the cost of full workforce packages. Using Burundi's per capita gross

domestic product (GDP) and the established cost-effectiveness thresholds (CETs) for maternal lives saved in low-income countries, the proposed investment falls within the CET for Burundi. Finally, a provider competence exam revealed generally poor EmONC skills among Burundian delivery care professionals, with doctors outperforming midwives and nurses. Most importantly, the current, routine EmONC training, costing nearly US$ 8,131.99 per trainee, does not significantly improve competence of medical doctors. This underscores the need to redesign training modules and assessment tools tailored for doctors separately from midwives and nurses.

PREFACE

This thesis is organised as follows. The first Chapter, Introduction, presents the study background including relevant literature and the aim and objectives. The second Chapter summarises the literature and frameworks that underpin this thesis. The third Chapter presents the methods and processes used to generate and analyse data and the ethical approvals I obtained. Then the results are organised into four Chapters. The first results chapter, corresponding to the fourth Chapter of the thesis, summarises the structural challenges facing Burundian EmONC facilities and corresponding budgetary requirements to close identified capacity gaps using a government perspective. The fifth thesis Chapter contains results of the EmONC competence exam conducted on delivery care providers. Given that routine EmONC training can be costly, this Chapter aims to evaluate EmONC training effectiveness and assess its importance in enhancing provider skills. The sixth Chapter demonstrates a framework to prioritise facilities based on current workloads, available resources, and mortality and presents findings from this analysis. The final results Chapter (i.e., the seventh thesis Chapter) builds upon the fourth Chapter by refining resource needs and cost estimates based on current workloads and presents findings from the application of decision tree modelling to predict the costs and benefits of various EmONC workforce investment scenarios. The eighth Chapter is the discussion and interpretation of findings. It is in this Chapter that I present the implications of my study for Burundian EmONC policy and practice and demonstrate my contribution to the global maternal and newborn health (MNH) policy discussions. The thesis ends with a conclusion that delineates salient takeaway messages and my postdoctoral prospects.

I anticipate five publications, the first two have already been published :

1. Habonimana, D., Leckcivilize, A., Nicodemo, C., & English, M. (2022). Addressing the need for an appropriate skilled delivery care workforce in Burundi to support maternal

and newborn health service delivery redesign (MNH-redesign): a sequential study protocol. *Wellcome Open Research*, *7*, 196. DOI: 10.12688/wellcomeopenres.17937.2

2. Habonimana, D., Leckcivilize, A., Nicodemo, C., Nzorironkankuze, J. B., Ndacayisaba, A., Bishinga, A., ... & English, M. (2024). Eight years into the horizon of aspirational maternal and newborn health pledges: a nationwide cross-sectional exploration of the Burundian EmONC network capacity and budget deficits. *BMJ open*, *14*(5), e083546.

3. Habonimana, D., Leckcivilize, A., Nicodemo, C., Nzorironkankuze, J. B., Ndacayisaba, A., Bishinga, A., ... & English, M. (2024). The application of Item Response Theory to revolutionise analysis of clinical competence of health workers: a cross-sectional vignette-based EmONC competence test of Burundian delivery care professionals. *BMC Health Services Research*. Submission ID b2f63d88-6ae2-4762-bc52-1d4b2d0d8e5e

4. Habonimana, D., Leckcivilize, A., Nicodemo, C., Nzorironkankuze, J. B., Ndacayisaba, A., Bishinga, A., ... & English, M. (2024). Prioritising human resource investments in a context of scarce resources: exploring options for the Burundian EmONC network. *Health Policy Open*. Submission ID: HPOPEN-D-25-00075

5. Habonimana, D., Leckcivilize, A., Nicodemo, C., Nzorironkankuze, J. B., Ndacayisaba, A., Bishinga, A., ... & English, M. (2024). A decision-tree model to evaluate the impacts of workforce investments aimed at strengthening Emergency Obstetric and Neonatal care (EmONC) facilities in Burundi.

LIST OF ACRONYMS

1PL	: One Parameter Logistic model
ABUBEF	: Association Burundaise pour le Bien-Etre Familiale
AFRO (WHO)	: WHO Regional Office for Africa
AGOB	: Burundian Association of Gynecology and Obstetrics
AIDS	: Acquired Immunodeficiency syndrome
AMDD	: Averting Maternal Death and Disability
ANC	: Antenatal Care
ANOVA	: Analysis of Variance
BEMONC	: Basic Emergency Obstetric and Neonatal Care
BIF	: Burundian Francs
CAM	: Carte d'Assurance Maladies
CBA	: Cost Benefit Analysis
CCA	: Cost Consequence Analysis
CEA	: Cost Effectiveness Analysis
CET	: Cost Effectiveness Threshold
CEMONC	: Comprehensive Emergency Obstetric and Neonatal Care
CHERG	: Child Health Epidemiology Reference Group
CHOICE	: Choosing Interventions that are Cost-Effective (WHO guidelines)
CHWs	: Community Health Workers
CI	: Confidence Interval
CMA	: Cost Minimisation Analysis
COVID-19	: Coronavirus disease 2019
CPAP	: Continuous Positive Airway Pressure
CSTS+	: Child Survival Technical Support Project
CUA	: Cost Utility Analysis
DALYs	: Disability-Adjusted Life Years
DHS	: Demographic and Health Survey
DPhil	: Doctor of Philosophy
EmONC	: Emergency Obstetric and Neonatal Care
ENAP	: The Every Newborn Action Plan
EPMM	: Ending Preventable Maternal Mortality
EWENE	: The Every Woman Every Newborn Everywhere
FASQ	: Facility Audit of Service Quality
FIGO	: International Federation of Gynecology and Obstetrics
FM (UoB)	: Faculty of Medicine of the University of Burundi
GBP	: British Pound
GDP	: Gross Domestic Product

HFC : The JICA Health Facility Census tool
HICs : High-Income Countries
HIS : Health Information System
HIV : Human Immunodeficiency Virus
HMIS : Health Management Information System
HRH : Human Resources for Health
ICC : Item Characteristic Curve
iCCM : Integrated community case management
ICD-10 : International Classification of Disease 10
ICL : Imperial College London
ICPD : International Conference on Population and Development
ICU : Intensive Care Unit
IHP : International Health Partnership
IPTp : Interment Preventive Treatment during pregnancy
IRT : Item Response Theory
IT : Information Technician
JICA : The Japan International Cooperation Agency
KMC : Kangaroo Mother Care
LBW : Low Birth Weight
LICs : Low-Income Countries
LiST : Lives Saved Tool
LLINs : Long-Lasting Insecticidal Nets
LMICs : Low- and Middle-Income Countries
LSHTM : London School of Hygiene and Tropical Medicine
MDGs : Millennium Development Goals
MgSO4 : Magnesium Sulphate
MMR : Maternal Mortality Ratio
MNH : Maternal and Newborn Health
MoH : Ministry of Health
MoNITOR : Mother and Newborn Information for Tracking Outcomes and Results
MRC : Medical Research Council
NDM : Nuffield Department of Medicine, University of Oxford
NHDP : National Health Development Plan
NMR : Neonatal Mortality Rate
OxTREC : University of Oxford's Tropical Research Ethics Committee
PBF : Performance-Based Financing
PCA : Principal Component Analysis
PI : Principal Investigator
PMTCT : Prevention of Mother-To-Child Transmission of HIV
PPH : Postpartum haemorrhage
QI : Quality Improvement

QoC : Quality of Care
QUALYs : Quality-Adjusted Life Years
QuEST : Quality Evidence for Health System Transformation
R-HFA : Rapid Health Facility Assessment
RCTs : Randomised Controlled Trials
RMNCAH : Reproductive, Maternal, Newborn, Child, and Adolescent Health
SAM : WHO Service Availability Mapping tool
SARA : WHO Service Availability and Readiness Assessment tool
SBAs : Skilled Birth Attendants
SD : Standard Deviation
SDGs : Sustainable Development Goals
SPA : MEASURE DHS Service Provision Assessment tool
SPC : Statistical Control Chart
SSA : Sub-Saharan Africa
STATA : Statistical software for data science
TCC : Total Characteristic Curve
TIF : Test Information Function
TLO : Thanzi La Onse model of care
UCL : University College London
UHC : Universal Health Coverage
UI : Uncertainty Interval
UK : United kingdom
UNDSA : United Nations Department of Economic and Social Affairs
UNFPA : United Nations Population Fund
UNICEF : United Nations Children's Fund
US$: United States dollar
USA : United States of America
USAID : United States Agency for International Development
WHO : World Health Organization
WISN : Workload Indicator for Staffing Needs

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Chapter 1. Introduction

The introductory chapter sets the study background with an overview of Burundi focusing on the health challenges and the key health policies shaping its healthcare system. First, I discuss the country's healthcare delivery system, emphasizing its four layers of service provision. Next, I narrow my focus to maternal and newborn health (MNH) which is the topic focus of my thesis. This section highlights the significance of MNH in the context of Burundi's overall health landscape. I then introduce the Burundian Emergency Obstetric and Neonatal Care (EmONC) network examining both global and national normative staffing standards for EmONC. This analysis situates my research within a broader global context and illustrates the relevance of international standards to local practices. The chapter concludes with a presentation of the research aims and objectives, outlining the specific goals of my study and the contributions it seeks to make to the field of MNH in Burundi.

1.1. Overview of the study country

Burundi is a low-income, landlocked country lying astride the East and Central Africa subregions. Nearly 87% of its population live below the World Bank's poverty benchmark of United States dollar (US$) 2.15 per day.[3] Approximately 90% of the population relies on subsistence farming and youth unemployment was estimated at around 65% in 2022.[3,4] The population has doubled from 6.1 million in 2000 to 13.6 million in 2023 and is projected to increase by 77% over the next 25 years, potentially reaching approximately 24.1 million by 2050. Covering an area of 27,834 km^2, Burundi is one of the most densely populated countries in the world with a population density of 442 people per km^2 in 2020.[5] Approximately one in four Burundians is younger than 15 years and females represent 50.3% of the population. Life expectancy at birth has improved significantly over the past two decades, rising by 19.6 years from 44.4 (43.5–45.4) to 64 (63.3–65.0) years between 2000 and 2021.[4]

Burundi has a tumultuous history marked by civil wars and conflicts with frequent political and armed upheavals from its independence in 1962 until the early 21st century which severely distorted its economic fabric and caused the healthcare system to crumble.[6-8] It is in 2005, following the 2000 Arusha peace agreement that aimed to end hostilities, that Burundi began to accelerate efforts to achieve universal health coverage (UHC) through a series of health policy reforms.[9,10] In fact, numerous health initiatives were implemented between 2005 and 2022 resulting in some improvements of health indicators albeit at an unsatisfactory pace.[11] For instance, Figure 1.1 shows that maternal mortality rate decrease by half between 2000 and 2022 although it remained high compared to neighbouring countries.

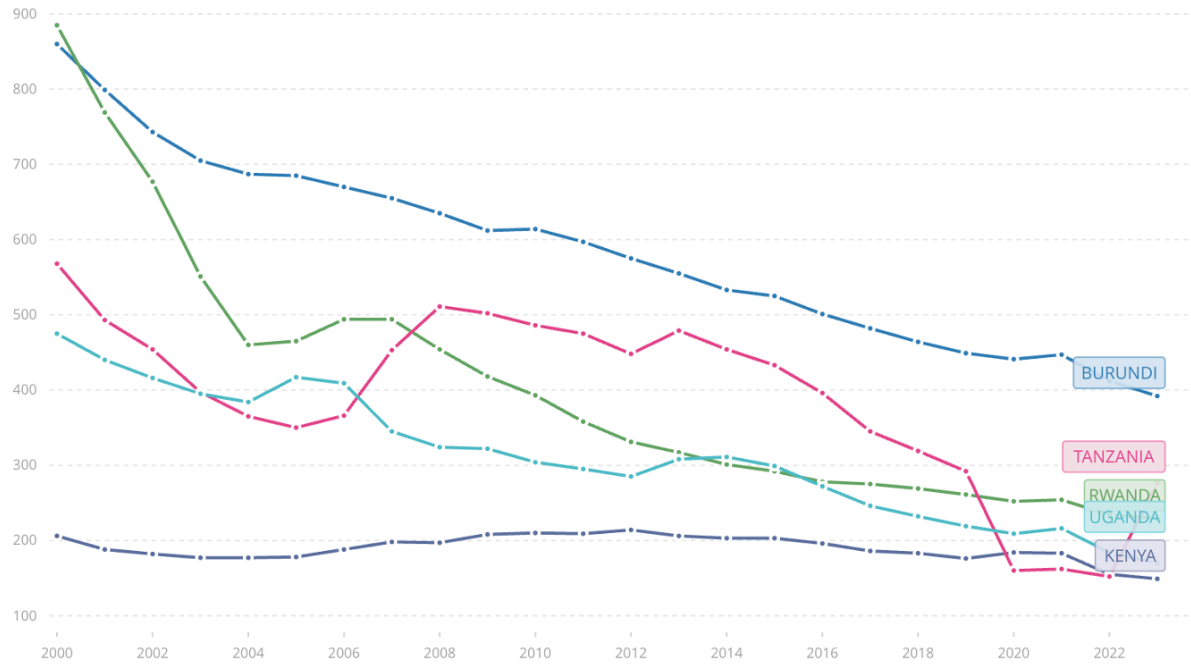


Figure 1.1 Maternal mortality ratio (modelled estimates, per 100,000 live births) - Burundi, Rwanda, Kenya, Tanzania, Uganda. WHO, UNICEF, UNFPA, World Bank Group, and UNDESA/Population Division. Trends in maternal mortality estimates 2000 to 2023. Geneva, World Health Organization, 2025. License : CC BY-4.0

Despite political resolve, Figure 1.1 indicates that Burundi's performance remains insufficient, suggesting that universal access to quality care is still unrealistic for most Burundians. For instance, the 2016-2017 Demographic and Health Survey (DHS) reported that 64% of Burundian women experienced financial barriers to accessing healthcare services over the course of five years preceding the survey while another 19% hesitated to seek healthcare services due to poverty.[12,13]

1.2. Major health policy reforms aimed to achieve UHC

In this section, I will explore the major health policies that Burundi implemented from 2005 until today. These include three ambitious consecutive strategic plans, the removal of user fees for pregnant women and children under 5 years, and the merging of the Ministry of Public Health and the Ministry of Acquired Immuno-Deficiency Syndrome (AIDS) into the Ministry of Public Health and AIDS Control, among other reforms.

From around 2004, Burundi embarked on a new journey to rebuild its health system in the aftermath of conflict laying the groundwork for UHC amidst the context of limited resources and poor relations with external donors.[14,15] At that time, the total health sector share amounted to 2.7% of the US$ 1.12 billion total national budget, corresponding to approximately US$ 1 per capita in health expenditure with *The Lancet* describing the country's health system as being in state of 'ruin' amid loosely coordinated and dwindling international aid efforts.[16,17]

Following the National High-Level Health Forum (*Etat Généraux de la Santé*) in 2004, Burundi developed its first National Health Development Plan (NHDP) in 2005. This plan outlined strategic guidelines for restructuring the health system including provisions to gradually increase the health budget share. Subsequent plans were formulated in 2011 and 2016, each involving multistakeholder consultations to design implementation strategies alongside financing provisions to advance the unfinished agenda towards UHC.[18] Another significant health policy concerned the exemption of user fees for maternal and child health services which was introduced in 2006.[19] This policy aimed to address the issue of in-hospital imprisonments of insolvent patients – mainly mothers following childbirths or caesarean sections – which was a major social barrier to accessing maternal and newborn care services.[20]

Simultaneously in 2006, Burundi began piloting Performance-Based Financing (PBF) initially in three (out of the 17) provinces, namely Bubanza, Cankuzo, and Gitega which expanded nationwide between 2009 and 2010.[21] PBF aims to reform health systems and respond to the 'how' problem for achieving UHC through incentivising quality care,

improving health system capacity, and strengthening human resources and infrastructure.[22,23]

Other notable health decisions and policies that Burundi embarked on from the early 2000s included: i) its accession to the International Health Partnership (IHP+) for UHC which is a global "compact" for achieving the Health Millennium Development Goals (MDGs) particularly focusing on African and Asian low-income countries (LICs) launched by the United Kingdom's (UK) Prime Minister in 2006–2007,[24] ii) the decentralisation of health services through the creation of health districts in 2009, and iii) the introduction of a community-based insurance scheme in 2013. I provide in Table 1.1 a comprehensive summary of key health policies and major health-related strategic decisions that Burundi implemented between 2000 and 2020, reflecting the country's political efforts to improve the healthcare system, address public health challenges, and promote the overall health development during this period.

Year	Health policy and major health decisions
2003	• Burundi secures the first Global Fund portfolio to address Malaria and HIV
2004	• National High-Level Health Forum
2005	• National Health Development Plan 2006 – 2015 • National Health Strategic Plan 2005 – 2010 • National roadmap to accelerate the reduction of maternal and neonatal mortality • First Global Fund grant to fight Tuberculosis
2006	• User fees removal for pregnant women and children under five years • Performance-based financing pilot programme in three provinces • Burundi joins the International Health Partnership (IHP+)
2009	• Creation of health districts • Institutional audit of the Ministry of Health (MoH)
2010	• Fusion of Ministries of Public Health and that of AIDS into one MoH • Demographic and Health Survey (DHS) • Scaling up of the performance-based financing
2011	• National Health Strategic Plan 2011 – 2015 • Reorganisation of the MoH following recommendations of the institutional audit • Burundi vision 2025
2012	• Signing of the IHP+ Compact 2012 – 2015
2013	• Launch of the Health Insurance Card '*Carte d'Assurance Maladies, CAM*'
2016	• National Health Development Plan 2016 – 2025

Table 1.1 Health policies and major health events between 2000 and 2020 – Burundi. Ministry of Health, Plan national de Développement Sanitaire 2011–2015 and 2016–2025.

1.3. Burundian healthcare delivery system

Now that I have briefly introduced the study country and some major health policies that were adopted over the past two decades in a bid to advance towards UHC, this section highlights how the Burundian healthcare delivery system is organised as a pyramid comprising four hierarchical levels: the central level responsible for decision-making, the intermediate level overseeing the implementation of health programmes, and the peripheral and community levels representing the operational and support system, respectively (see Figure 1.2).

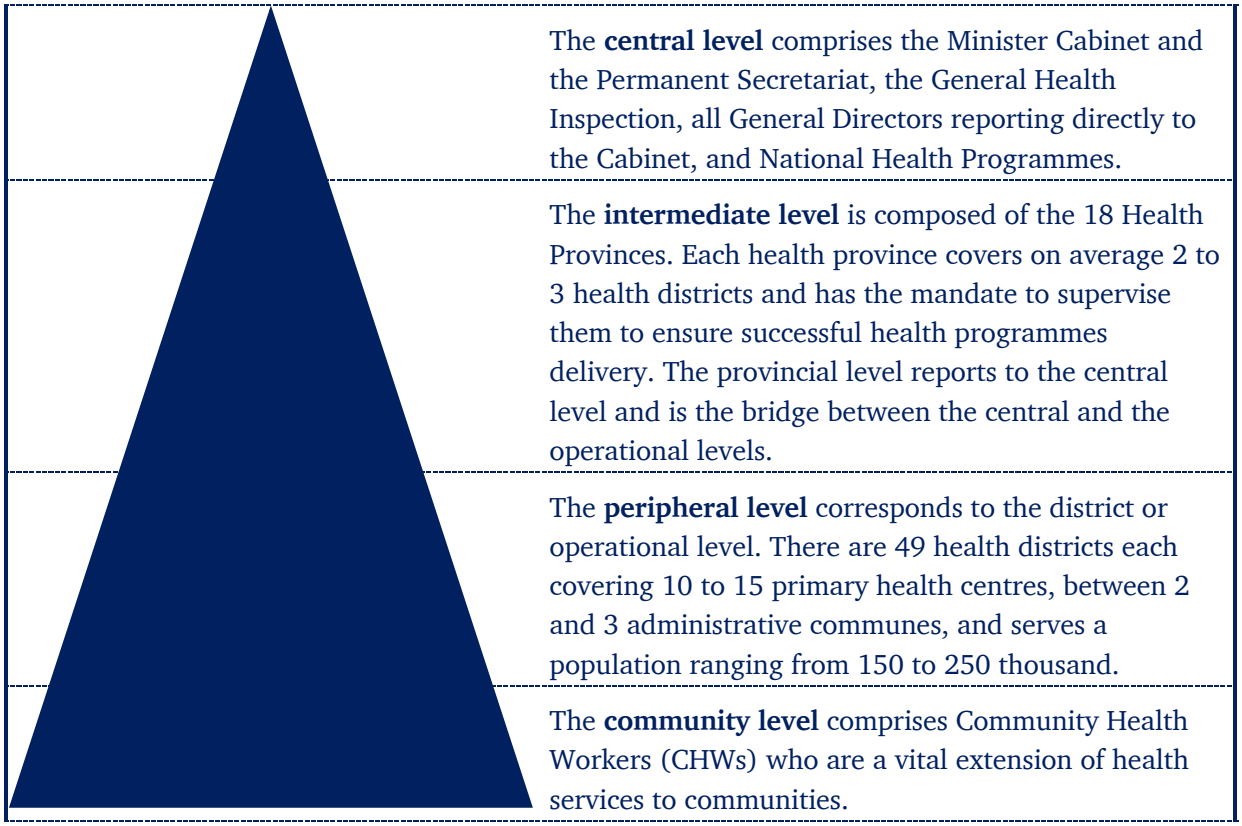


Figure 1.2 Burundian healthcare system pyramidal organisation. **Source**: *Ministry of Health, Norms and Standards for the implementation of the National Health Development Plan 2019–2025 in Burundi at central, intermediate, and peripheral levels. May 2019*.

As of 2025, Burundi has a total of 1,217 health facilities comprising 688 (56.5%) public, 340 (28.0%) private, and 189 (15.5%) religious and humanitarian facilities. Of these, 95.2% (1,159 out of 1,217) are primary health facilities while 46 (3.8%) are district or first-level hospitals. Additionally, the country has five regional (i.e., second-

level) hospitals all located in remote, rural areas and seven national (i.e., tertiary-level) hospitals six of which are situated in Bujumbura, the capital city.[25] Private hospitals are not officially classified within the health system. Thus, this facility account excludes private hospitals as all the 340 private facilities are primary care facilities and the 46 district hospitals along with the five and seven secondary and national-level hospitals are public facilities.

Conceptually, healthcare delivery in Burundi follows a hierarchical cascade starting from community-based care, progressing through primary health facilities, then the district hospitals, regional hospitals, and culminating at tertiary or national hospitals. Specifically, Community Health Workers (CHWs) primarily provide promotive and preventive health services alongside a defined curative package such as care for uncomplicated malaria, mild infant diarrhoea, and moderate malnutrition, amongst others.[26-28] Primary health facilities constitute the entry point for clinical care, staffed mainly by nurses and midwives who offer basic health care services. These facilities usually have a limited laboratory capacity but are without radiology and imaging services. Patients requiring advanced treatment are transferred to district hospitals which typically have more resources including medical doctors (general practitioners). The district hospital should perform surgery such as caesarean sections and wound suturing and should offer more advanced care including a select care package for preterm babies, full neonatal resuscitation, and basic imaging and radiology services.[29] The secondary and tertiary hospitals should be equipped with medical specialists across all major clinical disciplines and should have comprehensive laboratory and imaging services necessary for advanced care.[30] Although only one tertiary hospital is academically affiliated with the University of Burundi's medical school where medical doctors and medical specialists receive training, all tertiary hospitals are expected to have the capacity to train medical doctors and specialists across disciplines. Currently, policy discussions are ongoing to establish communal hospitals which would serve as the lowest level of hospital care interposed between the primary health facility and the district hospital but these plans have yet to materialise.

1.4. Burundi's commitment to MNH

In this section, I focus on Burundi's 3-decades journey committing to deliver on the MNH agenda and how the country formed in 2017 the EmONC network supported by a specific policy, all in a bid to improve maternal and newborn survival.

Burundi's commitment to MNH began in the mid-1990s following the International Conference on Population and Development (ICPD).[31] However, early efforts in this regard were hampered by recurrent wars and conflicts of that epoch. The country later aligned with the Millennium Development Goals (MDGs) agenda[32] in the mid-2000s making MNH a central focus of its health sector agenda. Indeed, all National Health Strategic Plans (details are in Table 1.1) underscore the government's political commitment to improving maternal and newborn survival.

Further, Burundi's current long-term vision, articulated in its 2020–2040 and 2040–2060 development frameworks, explicitly prioritises MNH. The country aims to reduce maternal mortality to fewer than 70 and 50 maternal deaths per 100,000 deliveries by 2040 and 2060, respectively. Similarly, neonatal mortality is targeted to decline to below 8 and 4 deaths per 1,000 live births respectively by 2040 and by 2060.[33]

Despite these commitments, utilisation of maternal health services remains suboptimal. For example, the 2016–2017 DHS found that only 49% of Burundian women who had a livebirth between 2012 and 2017 attended the recommended 4 antenatal care (ANC) visits,[34] a figure that declined to 42.3% in 2019 and further to 41.7% in 2023.[34,35] Coverage of ANC services also stagnated or declined, notably the proportion of HIV-infected pregnant women receiving prevention of mother-to-child transmission of HIV (PMTCT) services dropped from 70% in 2019 to 62% in 2023 with the rate of HIV-infected newborns born to women with HIV rising from 15% to 19.4% over the same period.

Similarly, coverage of malaria intermittent preventive treatment in pregnancy (IPTp) improved from 61.2% to 80.3%, yet this metric remains below optimal levels, and the use of long-lasting insecticidal nets (LLINs) decreased slightly from 82.7% to 80.3%.[35]

Facility-based deliveries have increased. However, even though the proportion of births attended by a skilled health provider rose from 60% in 2010 to 86% in 2018, it fell to 77% in 2020. The maternal mortality rate (MMR) was reported to be among the eight highest worldwide in 2015 alongside Liberia, Somalia, South Sudan, Nigeria, Chad, Central African Republic, and Sierra Leone with 712 maternal deaths occurring per 100,000 live births .[36] In 2020, approximately 494 (353–694) Burundian women out of 100,000 live births died of an obstetric cause with the national bureau of statistics projecting that about two Burundian women out of 100 are likely to die of obstetric complications particularly haemorrhage, infections, eclampsia, or unsafe abortion.[12,34,37]

Globally, the primary causes of maternal death are haemorrhage, hypertensive disorders, abortion, sepsis, embolism, and other non-specific causes.[36,38] The World Health Organization (WHO) reports that severe obstetric bleeding and hypotensive disorders alone accounted for 43% of maternal deaths globally between 2009 and 2020. These conditions are particularly prevalent and deadly in sub-Saharan Africa (SSA).[38] Evidence has proven that maternal deaths can be significantly averted by quality EmONC.[39-41]

1.5. The Burundian EmONC network: the dawn of a new era

The concept of EmONC was first introduced by WHO, The United Nations Children's Fund (UNICEF), and the United Nations Population Fund (UNFPA) in 1997 as a practical framework for the provision of lifesaving clinical services to improve maternal and newborn survival.[42,43] This framework became a cornerstone of the MDGs agenda 2000–2015 and has been further emphasised in the current Sustainable Development Goals (SDGs) agenda 2015–2030 which set even more ambitious targets for MNH.[44,45] In terms of progress, while the MDGs agenda achieved considerable milestones, they fell short of fully meeting maternal and newborn health targets.[46] Moreover, this progress was uneven among regions and countries and between population groups within countries, with the least developed settings achieving poor gains.[47]

Burundi, still battling with high maternal and neonatal mortality rates,[48] has committed to halving neonatal deaths from 23 to 12 neonatal deaths per 1,000 live births and reducing maternal mortality by 58% from about 334 to 140 deaths per 100,000 live births between 2015 and 2030. This agenda reinforces decades of commitment and efforts by stakeholders to address the problems associated with maternal and newborn survival and further builds on the existing maternal and newborn health subsidy programme initiated in 2006.[49] In 2017, Burundi operationalised the above commitment by establishing the "maternity network" comprising 53 hospitals and 59 primary health facilities designated as comprehensive and basic EmONC facilities (i.e., CEmONC and BEmONC) respectively. These facilities include 82 (73%) public and 30 (27%) religious and private facilities and are supported by a specific policy that defines maternal and neonatal health goals, outlining how these facilities should be strengthened with appropriate resources to maximise their readiness to provide quality care for emergency obstetric and newborn complications.[50]

The Burundian EmONC programme is principally supported by UNFPA, WHO, The Japan International Cooperation Agency (JICA), Pathfinder, and various local institutions involved in research and service delivery for MNH.[51] With 112 EmONC facilities for a country of 27 834 km^2 with approximately 13.6 million population in 2023, Burundi surpassed the WHO recommendation of one CEmONC and four BEmONC facilities per 500,000 population.[52,53] In many health districts, more than 97% of the population can access an EmONC facility within two hours (see Supplemental material 1). Additionally, user fees for pregnant women and children under five were removed in 2006.[54] These EmONC facilities perform roughly a third of all normal facility-based deliveries and manage nearly two-thirds of all obstetric complications.[50,51]

However, despite approximately 85% of deliveries taking place in health facilities,[48,55] the country does not seem to be making sufficient progress in reducing mortality as deaths continue to occur even inside the designated EmONC facilities. For instance, routine EmONC data collected from October to December 2021 show that 223 women and 1,183 newborns out of the 40,923 deliveries died (see details in Figure 1.3). Assuming that all births were single births as information on possible multiple births was not available, this amounts to a facility-based MMR of 545 per 100,000 deliveries

and a neonatal mortality rate (NMR) of 29 deaths per 1,000 live births. Both rates are higher than the population-based national averages and point to potential deficiencies within the EmONC network. Thus, these preview figures underscore the urgent need to re-evaluate and strengthen the quality of care provided within these facilities, an area where our research aims to support Burundian policymakers.

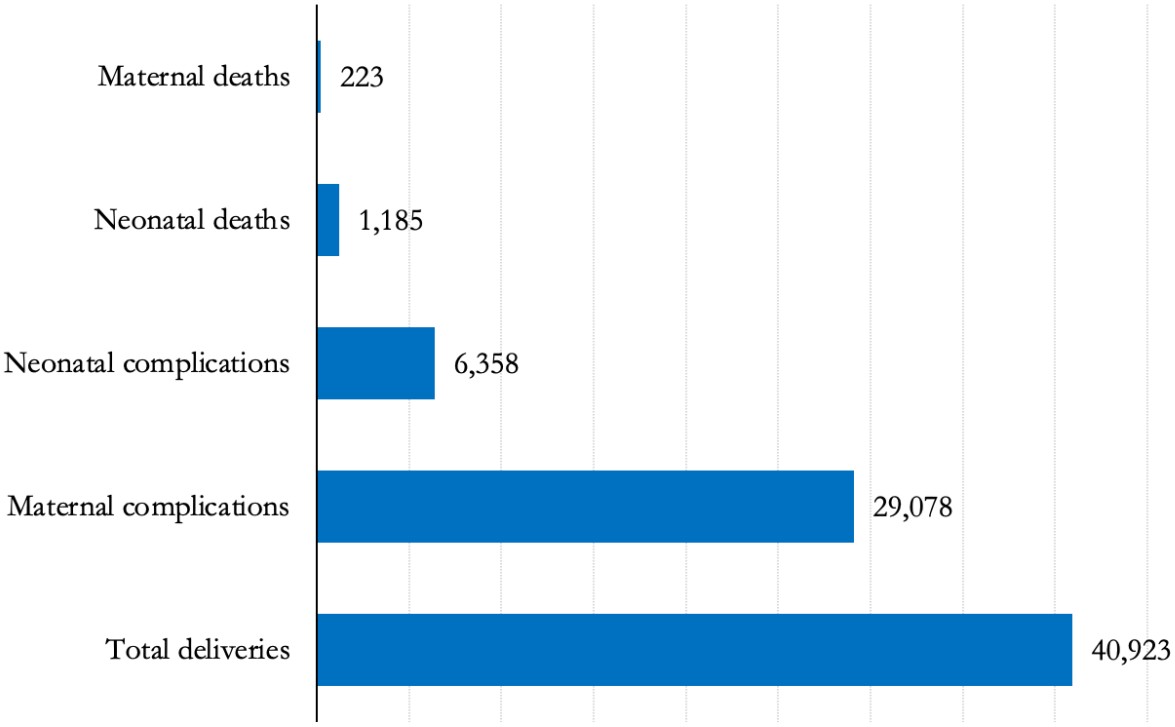


Figure 1.3 Maternal and neonatal deaths in Burundian EmONC health facilities. Total number of deliveries, maternal and neonatal complications and deaths over a period of three months from October until December 2021. **Data source**: *EmONC monitoring database, Ministry of Public Health and AIDS Control, Republic of Burundi*.

A systematic review of studies published from 2015 until 2020 that reported the causes of maternal deaths across 47 sub-Saharan African countries identified the leading causes of maternal deaths using the international classification of disease 10 (ICD-10) for maternal mortality. The review, which pooled data from 11,427 maternal deaths, found that the primary causes of maternal death are obstetric haemorrhage, hypertensive disorders, indirect complications, and pregnancy related complications (see details in Table 1.2).[56] When comparing this evidence on the leading causes of maternal deaths with maternity records from the Burundian EmONC facilities covering a period of 3 months from October until December 2021 (i.e., this period corresponds to the first three months of our Doctor of Philosophy; DPhil), the main causes of

maternal death in Burundi align with regional trends. In Burundi, pooled maternity records across EmONC facilities indicate that better management of obstetric haemorrhage alone would prevent approximately 40% of maternal deaths while addressing hypertensive disorders, uterine rupture, and maternal infections could save an additional 30% maternal lives. These findings reinforce the critical importance of high-quality EmONC services in reducing mortality.

Furthermore, a recent small-scale review of 184 maternal deaths in a rural Burundian EmONC hospital corroborated the need to focus on a limited set of conditions, revealing that obstetric haemorrhage was responsible for 72.2% of maternal deaths while eclampsia and uterine rupture accounted for 10.3% and 8.2%, respectively.[57]

The preceding local evidence which augments existing knowledge in the MNH field highlights the critical need for improved management of obstetric haemorrhage, hypertensive disorders, and uterine rupture.[58-60] Therefore, strengthening EmONC services and ensuring timely, quality care could substantially reduce maternal mortality in Burundi, aligning with the national and global MNH agenda.

Causes of maternal death	Evidence from the sub-Saharan Africa	Burundian EmONC health facilities
Obstetric haemorrhage	28.8% (26.5% - 31.2%)	41.61%
Hypertensive disorders	22.1% (19.9% - 24.2%)	13.89%
Pregnancy-related infections	11.5% (9.8% - 13.2%)	8.33%
Abortive complications	7.2% (5.3% - 9.1%)	1.39%
Non-obstetric complications	18.8% (16.4% - 21.2%)	13.89%
Uterine rupture	—	11.11%

Table 1.2 Leading causes of maternal deaths in sub-Saharan Africa and within the Burundian EmONC facilities. Causes of deaths in SSA drew on a systematic review of studies published from 2015 until 2020 across the 47 countries. Causes of maternal deaths within the Burundian EmONC were estimated using three-month routine data from October until December 2021. **Data source**: *EmONC monitoring database, Ministry of Health, Republic of Burundi*.

1.6. Situating my research into the global context

I have so far introduced the study country and described its health landscape focusing on MNH and the EmONC programme which started in 2017. In this section, I discuss global evidence and two major programmatic shifts around MNH. First, I explore the MNH 'radical service redesign' proposal introduced by The Lancet Commission on High Quality Health Systems in the SDG Era (i.e., the Quality Commission) in 2018. I describe this redesign proposal and explore its relevance and applicability to low- and middle income countries (LMICs). Next, I explore the EmONC model, document the impact of EmONC services on maternal and newborn mortality in LMICs, and compare this approach with the redesign to draw practical and policy-relevant conclusions.

Globally, progress in reducing maternal mortality has stalled during the SDGs era compared to the preceding MDGs period. Indeed, between 2015 and 2020, the estimated annual reduction in MMR ratio was only 0.04% (uncertainty interval, UI, ranging from 1.1% to 1.6%), whereas the annual reduction was 2.7% (UI from 2.0% to 3.2%) between 2000 and 2015.[61] Further, a recent publication in *Nature Sustainability* that synthesised over 3,000 studies from 2016 to 2021 on the political framework of the SDGs revealed that this global agenda has exerted a discursive political impact on institutions and policies, yet it has largely fallen short of its promises with limited transformative effects.[62] This occurs even as global expenditures on the SDGs exceed US$ 20 trillion annually, a figure expected to rise in the remaining five years leading up to the 2030 deadline.

Maternal mortality trends reveal significant inequalities across regions and between countries. Compared to other regions, SSA remains the only region with a 'very high' MMR, estimated at 545 (UI ranging from 477 to 654) maternal deaths per 100,000 live births; 136 times higher than in Australia and New Zealand for instance.[61] In 2020, Sub Saharan Africa (SSA) accounted for roughly 70% of maternal deaths globally,[61] a pattern that persisted over the past two decades.[36] It was also estimated that a girl born in SSA in 2020 faces approximately 400 times higher the lifetime risk of maternal death than her counterpart in Australia or New Zealand.[61] Contrary to LMICs, high-income

countries (HICs) have achieved significant and consistent reductions in MMR since the 1990s with projections indicating continued declines until 2050.[63] For instance, a regional study that used data from 37 HICs reported a 59.5% decline in MMR from 26 (95% Confidence Interval, CI, ranging from 22 to 29) maternal deaths per 100,000 livebirths in 1990 to 10 (95% CI, ranging from 6 to 14) deaths per 100,000 live births in 2021, a decline consistent across age groups.[63]

These disparities among regions indicate that if the world aspires to achieve the SDGs targets of fewer than 70 maternal deaths per 100,000 live births and below 12 newborn deaths per 1,000 live births by 2030, urgent and substantial shifts in focus, funding, and interventions are necessary. Without decisive action today, the global MMR average in 2030 is projected to be around 222 maternal deaths per 100,000 live births; more than three times higher than the anticipated SDGs target of 70 maternal deaths per 100,000 live births.[61] In fact, assuming that the MMR continues to decline at the same pace observed between 2000 and 2020 would be unrealistic given current circumstances. Already, from 2015 until 2020, many countries experienced stagnation or even worsening of their MMR. Therefore, even under the optimistic scenario of MMR decline at the 2000–2020 pace, the MMR would still be approximately 180 maternal deaths per 100,000 live births by 2030, a figure more than twice the SDG target.

Therefore, achieving the SDG MNH goals by 2030 requires an average MMR reduction rate of 11.6% annually until 2030, and this poses a significant and unprecedented challenge as only three countries in the whole world have ever achieved this reduction in any year from 2000 until 2020. Moreover, numerous crises such as epidemics and pandemics threaten to reverse MNH gains as illustrated by Corona virus disease 2019 (Covid-19) which caused maternal death tolls to rise globally from an estimated 282,000 deaths in 2020 to 322,000 deaths in 2021.[64] This setback is currently worsened by the reductions in global assistance for development notably due to the United States of America's (USA) decision to cut all funding portfolios for the United States Agency for International Development (USAID) overseas programmes.

A decade ago, evidence indicated that primary care facilities in LMICs deliver nearly half of facility-based births despite often lacking essential resources such as skilled birth attendants (SBAs) trained in EmONC who could manage the most fatal emergency

complications.[65,66] Moreover, primary health facilities in these countries often lack adequate human resources and essential equipment, supplies, while laboratory and imaging services including surgery services are often only available at hospital level.[65-67] Furthermore, primary facilities are in many cases located far from hospitals posing a threat to inter-facility communication and complicating timely referrals when a woman develops an obstetric complication.[68] These challenges prompted initiatives aimed at improving maternal and newborn survival by advancing 'MNH service redesign' based on the premise that improving care processes in primary health facilities alone would be insufficient to substantially reduce maternal and neonatal mortality.[69]

1.6.1. The MNH service redesign: a structural reform proposal

In 2018, *The Lancet* Global Health Commission on High Quality Health Systems in the SDG Era (the Quality Commission) proposed a comprehensive MNH service redesign premised on reorganising health systems by ensuring that the right care is provided at the right level of the healthcare system and by the right provider.[70] The core principle of such a system redesign involves shifting all deliveries to or near to hospitals or other facilities offering advanced care to promote best practices and quality standards.[71] This model, schematised in Figure 1.4, requires investments in high-quality hospitals with sufficient EmONC resources including adequate personnel such as competent midwives alongside efforts to boost the quality of antenatal, postnatal and newborn care at primary health facilities.[71] Additionally, the model advocates making needed investments to expand geographic access, removing financial hardship, and engaging communities, all under strong political leadership.[71]

The service redesign model depicted in Figure 1.4 was piloted in Kenya by a team of Harvard scholars in 2019 and 2020 to assess its feasibility and acceptability in a rural setting. The pilot focused on Kakamega county, which recorded an estimated 70,084 deliveries in 2018; around 35% of which were home-based deliveries and 28% occurred in primary health facilities. In 2019, Kakamega had 205 health facilities including 13 hospitals performing approximately 37% of all deliveries. The redesign consisted of identifying in collaboration with local stakeholders, 16 hospitals spread across the 12 sub-counties of Kakamega county. The distribution of these designated hospitals under

the service redesign model aimed at ensuring that 100% of women lived within 2 hours of travel time to a designated hospital while 99% lived within 1 hour commute time and 85% had access to a designated hospital within 30 minutes of travel time. These 16 hospitals already had an oversight role or contractual relationship with peripheral primary facilities and collectively reportedly performed more than half of countywide deliveries.

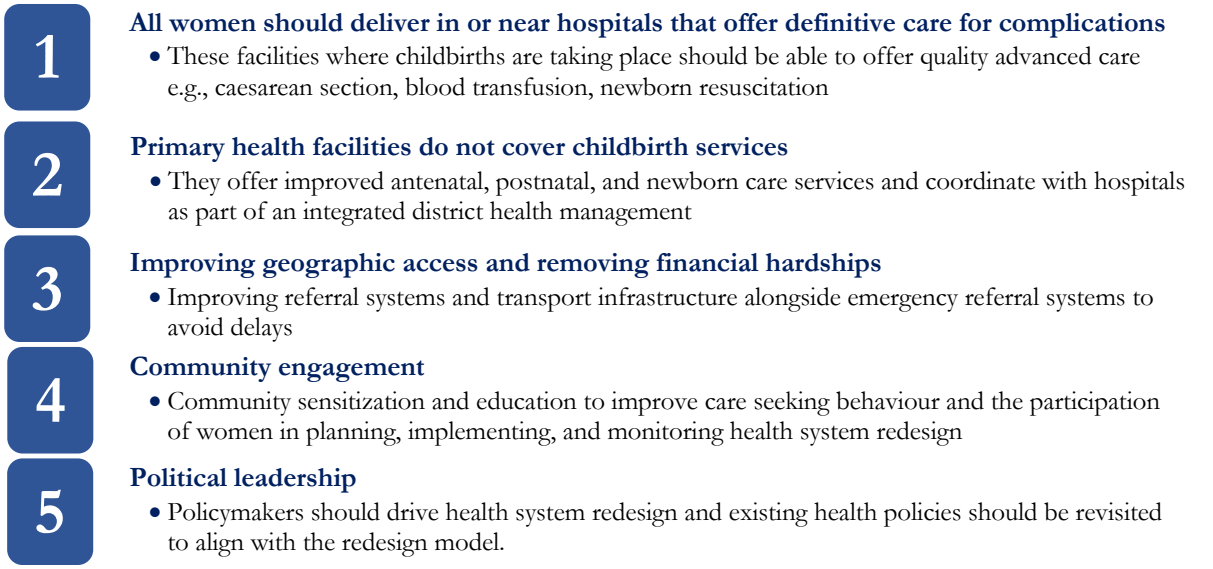


Figure 1.4 Adapted core principles of health system redesign for maternal and newborn care. Health system redesign for maternal and newborn survival: rethinking care models to close the global equity gap. **Source**: *Roder-DeWan, S., Nimako, K., Twum-Danso, N. A., Amatya, A., Langer, A., & Kruk, M. (2020). Health system redesign for maternal and newborn survival: rethinking care models to close the global equity gap. BMJ Global Health, 5(10).*

An accessibility and feasibility assessment involving examining existing infrastructure, human resources, and acceptability among health care providers and service users revealed significant challenges. These included problems with the road system that hinders geographic access while hospital infrastructure was estimated to fall short of 137 total additional beds to support the redesign conditions. Additionally, the number of doctors would need to more than triple to meet the redesign requirements, amongst other resource needs.[72] Although perceived acceptability among users and providers was high with many expressing strong support of the service redesign proposal, such a redesign faced fierce criticism and significant opposition, reflecting the complex realities on the ground.[72,73]

The MNH service redesign model has advantages and downsides. Shifting obstetric care from rural, isolated primary health facilities to larger facilities likely in towns and cities could improve recruitment and retention of midwives and doctors[74] and reduce service demands to these peripheral smaller facilities thus allowing them to focus on services that are their core competence such as promotional and preventive care including antenatal care and childhood immunization. This in turn would decongest hospital outpatient clinics.[75] Nonetheless, implementing such a redesign at scale in LMICs presents practical challenges. First, the proposal assumes the presence of a sufficient number of hospitals accessible to the population and that these hospitals provide high quality care; conditions that are often unmet in most LMIC settings. For instance, I showed earlier that 1,159 out of 1,217 facilities in Burundi (i.e., 95.2% facilities) are primary health facilities with hospitals, most of which are located in cities and towns, representing less than 5% of all facilities which limits access for the rural majority.[25] Furthermore, many hospitals in LMICs lack the necessary resources to offer quality care and cannot produce excellent health outcomes.[70] Consequently, redirecting births to low-quality and poorly accessible facilities (hospitals) could increase iatrogenic complications and lead to disrespectful care especially during overcrowding.[76] Such shifts may inadvertently worsen service quality and deepen existing socioeconomic and rural-urban disparities in access to essential maternal and newborn health services.[77]

In many LMICs, the MNH service redesign could simply mean a rhetorical relabelling of hospitals without accompanying tangible efforts to strengthen them, creating therefore an illusion of enhanced capacity or quality while masking the underlying deficiencies in infrastructure, staffing, or resources.[72] Under these conditions, the service redesign could yield unexpected outcomes, overwhelm existing staff and resources, and potentially compromise patient safety and trust in the health system.

1.6.2. The EmONC framework: an organisational reform

An alternative model widely adopted in LMICs is the EmONC framework. While this model shares similar principles with the health system redesign, it does not advocate relocating all deliveries to hospitals. Instead, the EmONC framework posits establishing

a network of selected facilities, both primary health facilities and hospitals, and strengthening them to provide optimal quality childbirth care including for complications. These facilities should be equitably distributed to ensure that all women can access them within approximately two hours of travel. They must be well-functioning and capable of delivering the full set of EmONC signal functions (see Table 1.3) as relevant[78] and should possess adequate infrastructure, skilled delivery care personnel, essential equipment, drugs, and supplies to enable provision of quality care which should be complemented by a functional referral system.[79,80] This approach aims to improve access and quality of maternity care across communities, especially in resource-limited settings.[81]

Almost all the maternal deaths due to pregnancy related complications are preventable using cost effective, evidence-based interventions most of which are feasible even in LMICs.[82] The impact of enhancing maternity care through EmONC services on maternal and newborn survival has been demonstrated in many LMICs.[83] A systematic review of 58 randomised controlled trials (RCTs) and quasi-experimental studies examining the impact of EmONC interventions on maternal and newborn mortality rates concluded that quality EmONC services significantly reduced maternal mortality and case fatality rates by 55% and 40% respectively.[84] In some countries such as Tanzania for instance, MMR reduction dropped 80% from 933 to 186 maternal deaths per 100,000 live births in facilities offering high-quality EmONC services over a period of six years.[85]

The positive effect of high-quality EmONC services has been confirmed in many other contexts. For instance, a controlled before-and-after study conducted in South Africa from 2011 until 2016 concluded that maternal mortality declined markedly in facilities implementing EmONC services. Results indicate that 2,212 maternal deaths occurred out of 1,248,333 live births in facilities receiving EmONC intervention compared to 5,961 maternal deaths out of 5,439,870 live births in control facilities. Thus, while maternal mortality increased by 2.7% in control facilities over the six-year period, it declined by 29.3% in facilities implementing the EmONC protocol. Further, the risk of a woman dying of both direct and indirect obstetric causes was significantly lower in EmONC facilities (i.e., risk ratio of 0.71; 95% CI: 0.66–0.77) compared to the control facility group.[86] Also, documented evidence consistently proves that maternal benefits

of EmONC extend to neonatal health outcomes with many LMICs reports confirming that better maternal care improves neonatal survival.[87]

EmONC signal function	BEmONC	CEmONC
Obstetric care		
(1) Administer medication to treat PPH	Yes	Yes
(2) Administer parenteral antibiotics	Yes	Yes
(3) Administer magnesium sulfate	Yes	Yes
(4) Remove retained products of conception	Yes	Yes
(5) Perform manual removal of placenta	Yes	Yes
(6) Perform assisted vaginal birth	Yes	Yes
(7) Provide intravenous replacement therapy	Yes	Yes
(8) Administer antenatal corticosteroids	n.a.	Yes
(9) Perform caesarean section	n.a.	Yes
(10) Perform blood transfusion	n.a.	Yes
Neonatal care		
(11) Perform newborn resuscitation with bag and mask	Yes	Yes
(12) Initiate and support early and exclusive breastfeeding	Yes	Yes
(13) Administer parenteral antibiotics	Yes	Yes
(14) Practice immediate KMC for preterm and LBW infants	Yes	Yes
(15) Administer oxygen therapy with pulse oximeter	Yes*	Yes
(16) Provide thermal care with radiant warmer or incubator	n.a.	Yes
(17) Provide CPAP	n.a.	Yes
(18) Provide phototherapy	n.a.	Yes
(19) Perform blood transfusion	n.a.	Yes
(20) Enable assisted feeding with expressed breast milk with cup and spoon and tube feeding	n.a.	Yes
(21) Provide intravenous fluids	n.a.	Yes

Table 1.3 Emergency obstetric and neonatal care signal functions. **Sources**: *World Health Organization, Mother and Newborn Information for Tracking Outcomes and Results (MoNITOR) supplemented with the revised EmONC Framework, published by The London School of Hygiene and Tropical Medicine (LSHTM) and the Averting Maternal Death and Disability programme of the Columbia Mailman School of Public Health*. *At BEmONC facilities, for stabilisation and transportation only. CPAP (continuous positive airway pressure); KMC (kangaroo mother care); PPH (post-partum haemorrhage). BEmONC facilities should arrange an ambulance with trained and equipped provider and refer to a facility that can provide definitive care.

However, evidence increasingly highlights that weak and fragile health systems hamper the effective implementation of EmONC. In fact, despite its cost-effectiveness and relevance to LMICs, many countries struggle to fully operationalise EmONC.[88,89] For instance, in Nigeria, less than 6% of designated EmONC facilities meet the minimum quality standards and can only handle 3.9% of complications with 84% of maternal deaths in these settings being attributed to direct obstetric complications.[90] Similarly, a multi-country study encompassing Kenya, Malawi, Sierra Leone, Nigeria, Bangladesh, and India revealed that, despite political commitments, only 1 in 4 hospitals designated as CEmONC facilities and just 2.3% of primary facilities expected to offer basic EmONC care had the necessary resources to provide quality EmONC care.[91] Therefore, if LMICs fail to strengthen and fully operationalise their EmONC networks, supported by routine quality assessments and continuous quality improvement, they will continue to fall short of maternal and neonatal health gains.[92] To produce the intended results under the EmONC framework, the following conditions are necessary:[88,93-96]

1. **Adequate infrastructure**: designated EmONC facilities should have needed equipment (e.g., delivery rooms, delivery beds, etc.) with reliable utilities such as water and electricity as well as infection control and prevention mechanisms to ensure quality and safe care;

2. **Service availability and readiness**: designated EmONC facilities should have needed resources to offer the full set of signal functions as detailed in Table 1.3;

3. **Adequate skilled delivery care providers**: designated EmONC facilities should have enough and competent delivery care personnel, who are further motivated and sufficiently supported, capable of performing EmONC signal functions efficiently and safely;

4. **Effective referral system**: designated EmONC facilities should be connected by a robust referral system with prompt transportation and communication systems to handle cases beyond facility capacity while ensuring timely care;

5. **Reliable supply chain**: designated EmONC facilities should consistently have the full pack of essential medicines, equipment, and supplies necessary for EmONC services;

6. **Monitoring and data use**: designated EmONC facilities should be supported by regular collection, analysis, and use of data to monitor performance, identify gaps, and guide continuous improvement efforts;

7. **Health system strengthening**: the EmONC network should be supported by protocols and policies, governance, and financing mechanisms that prioritise MNH alongside explicit strategies to sustain service availability and provision.

1.7. Strengthening Burundian EmONC facilities: a focus on human resources

I began this Introduction chapter with an overview of Burundi and its efforts to attain UHC following four decades of recurrent civil wars and political turmoil emphasising on MNH which is the central theme of my thesis. I then introduced the Burundian EmONC network which was formed in 2017 in the pursuit of MNH gains to meet the SDG 3.1 and 3.2 targets related to maternal and newborn health, respectively, demonstrating using routine records that this EmONC programme has failed to achieve its intended objectives. I continued the chapter with a review of two major frameworks, the health system redesign concept proposed by a Lancet Commission and the EmONC model developed and promoted mainly by UNFPA and WHO, exploring the advantages and limitations of each framework relative to LMICs. The forthcoming section delves into the Burundian EmONC model. While my thesis explored a comprehensive package of resources, I particularly focus on human resources as they constitute the cornerstone of quality care frameworks and are an important challenge for most LMICs.

Achieving high-quality maternal and neonatal care through the EmONC model requires sufficient and well-trained health personnel. The WHO quality of care (QoC) model emphasises eight domains that encompass both the structure and process elements of care at health facility level (details are provided in Section 2.2).[97,98] Facility structure

includes essential resources such as physical infrastructure, maternity and neonatology equipment, essential medicines and supplies, and human resources.[97,99,100] Adequate resources (structure) supporting effective processes of care are fundamental for improved health outcomes. The critical role of skilled birth personnel including qualified nurses, midwives, doctors, and obstetricians in delivering quality care has been established worldwide.[101-103]

Burundi aspires to achieve an ambitious maternal and newborn health agenda that aligns with the current global targets[45,104] by reducing maternal mortality from 334 deaths per 100,000 live births in 2015, one of the world's highest maternal mortality ratios,[36,105] to below 140 deaths per 100,000 live births by 2030.[48] At the same time, the country aims to halve neonatal mortality, from 23 deaths in 2016[106] to below 12 deaths per 1,000 live births by 2030.[48] To meet these targets, Burundian policymakers will need to strategically allocate resources, redesign maternal and neonatal health care provision to ensure that all mothers and babies receive adequate intrapartum and postpartum care. Delivering such services hinges on having sufficient, appropriately skilled human resources who are competent to offer adequate, timely, and life-saving maternal and newborn care.[107-109]

Currently, Burundi operates a network of 112 health facilities offering EmONC services, 59 primary care facilities dispensing basic emergency services and 53 hospitals offering comprehensive care.[51] In this country, delivery care is officially provided by qualified nurses, midwives, medical doctors, or obstetricians depending on the availability of these human resources and the clinical need. Except for obstetricians, all these delivery cadres should have initial pre-service and then biennial in-service EmONC training to be recognised as "skilled delivery care personnel."

With attention to human resources for health (HRH), Burundi's aspiration to deliver on a universal health coverage agenda is undermined by severe shortages and maldistributions of health workers.[110] Concerning the quantity of trained health personnel for instance, the number of medical doctors per 10,000 population increased from 0.28 in 2010 to 1.00 in 2017 but remains below the WHO recommended threshold.[111] Moreover, with a total population estimated at 13.6 million, Burundi has fewer than 200 medical specialists across all disciplines of whom more than 95% are

concentrated in Bujumbura capital city which serves only 2.7% of the population.[111] Noting that Burundi's population is mostly youthful as depicted in Section 1.1,[112] this country must determine and establish the appropriate number and geographic distribution of designated facilities offering basic and comprehensive EmONC, ensuring equitable access across regions.

My research builds on the aforementioned background and aims to address some of the concerns raised. In Burundi, there is limited empirical evidence regarding structural and workforce challenges facing the EmONC facility network as well as the actual needs that should inform effective planning and policy development. Importantly, existing partial evidence highlights that Burundi faces significant barriers to the delivery of quality EmONC service. Key challenges include inefficient resource allocation, shortages and maldistribution of human resources, increasing workloads, and gaps in essential supplies and medications.[113] Additionally, weaknesses in training curricula, poor coordination and harmonisation of medical and paramedical education, and insufficient or outdated in-service training further hinder service quality. These issues collectively undermine the provision of quality EmONC services across the country.[113] Specifically, since 29.5% of the total health budget is devoted to human resources for health, their efficient and effective allocation is crucial for optimising the health system performance.[114]

1.8. Global and regional health workforce account and distribution

Globally, there was an estimated 52.5 million health workers across professions in 2024. As can be seen in Figure 1.5, the distribution of health workers across WHO regions from 2013 to 2023 reveals significant disparities in workforce size and composition. The West Pacific region has the largest total stock with approximately 15.3 million health workers who comprise a substantial and balanced skill-mix with an estimated 4.5 million medical doctors, 8.3 million nurses, and 0.7 million midwives. Similarly, the Americas region has a large health workforce, totalling around 11.8 million health workers. This stock is predominantly made up of nurses (i.e., 7.4 million) and doctors (i.e., 3.1 million) which indicates a relatively balanced distribution of

health personnel and a presence of a skill-mix that enables the provision of most health care needed in health facilities.

In contrast, regions like Africa have much smaller health workforce accounts, with only about 0.4 million doctors and 1.8 million nurses. Given population sizes, this highlights a critical shortage of health workers that could impact healthcare delivery. The Eastern Mediterranean and South-Asia regions have moderate workforce sizes, with around 2.8 and 7.5 million health workers, respectively. In these regions, nurses form the majority of workers. The European region stands out with a sizeable and balanced workforce amounting to approximately 12.5 million, a much large health worker stock for its population size.

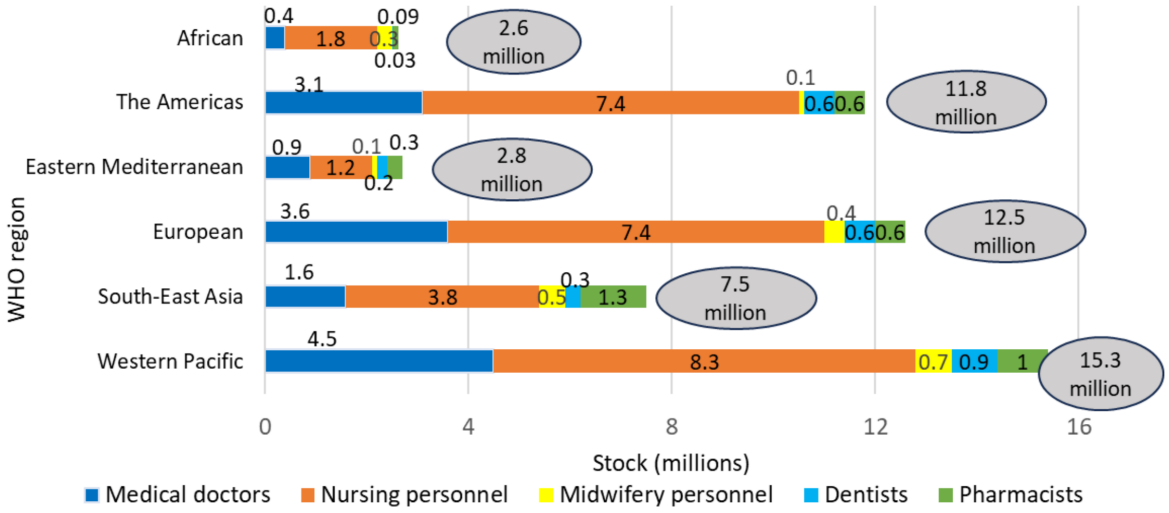


Figure 1.5 Estimated stock of health workers by WHO regions, from 2014 until 2023. Stock totals are rounded. **Source**: *World Health Organization. Health and care workforce. Global strategy on human resources for health: workforce 2030. Report by the Director-General. Executive Board 156th session, EB156/15. 2024.*

With respect to shortages, Africa has the largest share of the global health workforce shortage, accounting for nearly 42% of the total health worker deficit. The South-East Asia region accounts for 24% of the deficit. Other regions namely Europe, East Mediterranean, and the Western Pacific have smaller proportions of shortages although they also lack a complete, needed workforce.

Projections for 2030 workforce stock are presented in Figure 1.6 and show continued and even pronounced disparities in health worker shortages. Africa is expected to

account for more than half of the global health workforce shortage (i.e., estimated at 51%) highlighting the ongoing critical gap in this region. Conversely, the Western Pacific and European regions are expected to have the smallest shares of workforce shortages, estimated at 4 and 3% respectively.

Overall, the above variations in health worker density and projected deficits by 2030 emphasise the uneven distribution and capacity of health workforce stocks across regions and underscore the need for targeted strategies to address health workforce issues particularly in Africa.[115]

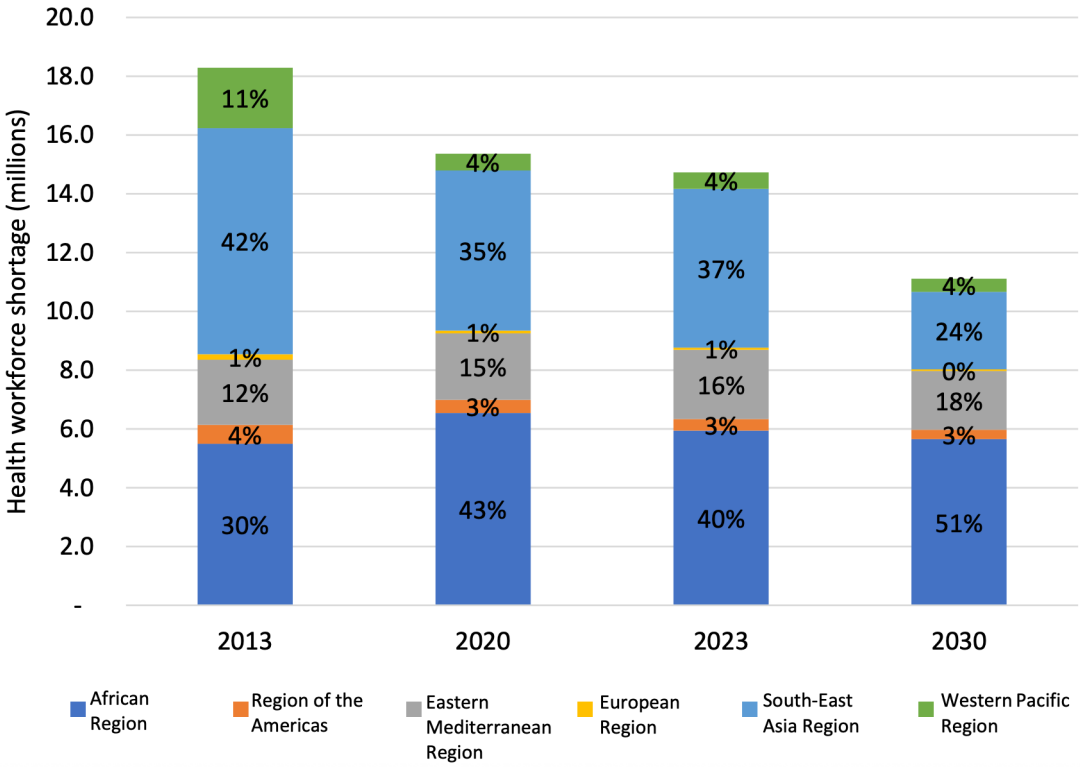


Figure 1.6 Distribution of the global health workforce shortages by WHO region for 2013, 2020, 2023 with projections for 2030. **Source**: *World Health Organization. Health and care workforce. Global strategy on human resources for health: workforce 2030. Report by the Director-General. Executive Board 156th session, EB156/15. 2024.*

Human resources for health are fundamental to the functioning of healthcare systems and represent vital capital for delivering care.[116] The size, skill-mix, and equitable distribution of competent health workers largely determine the performance and resilience of health systems.[117] Recognising this and in line with the above workforce issues facing Africa, WHO in the African Region (WHO AFRO) developed in 2006 a standardised guideline to assist countries in formulating realistic and effective HRH

policies, which helped many African countries develop their own HRH policies.[118] By 2015, for instance, 72% of countries in this region had formulated a national HRH strategy.[119] However, despite these efforts, many studies including a comprehensive Lancet systematic review that examined the availability of HRH globally found that most African countries including Burundi continue to face critical challenges to address health workforce shortages and maldistributions.[117,120-122] Similar issues have been documented in several countries such as Ghana,[123] South Africa,[124] Tanzania,[125] Kenya, Ethiopia, Uganda, and Nigeria.[126-129] This widespread HRH challenge points to the need to examine HRH policies developed in most African countries and explore the levels of HRH policy implementation particularly because developing HRH policies and strategic plans is a complex process requiring support from experts, accurate data, careful analysis and inputs and buy-in from stakeholders and policymakers.[130] Weakness in HRH policy development and planning have led to inefficient healthcare delivery systems, pushing back efforts to increase access to quality care for all.[131,132]

1.9. Production, absorption, and retention of HRH in Burundi

Burundi has three universities that train medical doctors, one public and two private institutions. The public university (University of Burundi) began to graduate doctors in 1981 while the other two private universities graduated their first cohorts of medical doctors in 2003 and 2012, respectively. Until today, the University of Burundi remains the only institution providing specialist training across all medical disciplines.

In addition, Burundi has one public and two private universities dedicated to training nurses and midwives, with the oldest (National Institute of Public Health) graduating its first cohort in 2001. There are also another four public and five private high schools that train nurses of various levels, from assistant nurses (A3) to fully qualified nurses (A2). Two of these secondary schools began graduating nurses in the 1980s and the remaining started to operate between 2000 and 2012.

The total estimate of health worker stock produced over the past decade is provided in Table 1.4. In total, Burundi produced an estimated 16,572 nurses from 2010 until

2021, along with 1,065 midwives, and 1,664 medical doctors excluding specialists. Data on the training of medical specialists is limited as many complete part of their final training abroad and often do not return.

Regarding health workforce absorption, as of 2017, the government of Burundi through the MoH reported a total account of 647 medical doctors and an estimated 7,332 and 103 nurses and midwives employed in the public health sector with an estimated 996 workers projected to retire before 2020. Health worker absorption within the private sector was estimated to be 437 medical doctors, 57 midwives, and 1,739 nurses. Therefore, Burundi's inability to effectively absorb trained health workers suggests the presence of a substantial pool of unemployed health professionals. In theory, some of the current health workforce deficits could potentially be addressed with the existing stock of unemployed health professionals.

Burundi's HRH retention has long been a critical challenge. In 2004 for instance, this country was classified among 11 LMICs with a substantial HRH drain brain, exceeding 13% of medical personel,[133] driven by insufficient salary, poor working conditions, overwhelming patient loads, insufficient training and career opportunities, inadequate research investment and infrastructure, and political instability.[134] A 2017 joint World Bank and UNICEF report documented that Burundian health workers were chronically underpaid with newly recruited medical doctors earning approximately US$ 250 per month; a figure failing to capture market distortions including a substantial gap between the official and parallel (black) exchange rates where the official rate currently coverts roughly 1 US$ to Burundian Francs (BIF) 3,000 while the black market rate amounts to about BIF 7,000.[135] Under 'real-life' conditions, a Burundian medical doctor could be earning closer to US$ 170 monthly-equivalent at the parallel market rate. While official evidence is sparse, the Burundian Minister of Health noted in a December 2024 parliamentary address that a Burundian medical specialist earns about BIF 1,200,000 per month (roughly US$ 407 at the official rate and US$ 171 on the parallel market), versus colleagues in Rwanda earning US$ 897 and those in Tanzania and Kenya receiving approximately US$ 1,300 and US$ 3,000, respectively. The Minister also indicated that some 3,000 Burundian doctors have emigrated to Rwanda, Kenya, and European destinations mainly France and Belgium in the wake of political

upheavals since 2015.[136] The persistent failure to adjust remuneration in the face of rising workloads and limited equipment and infrastructure has thus sustained a net outflow of medical talent, limiting Burundi's capacity to retain HRH and reverse the brain drain. The massive exodus of health workers undermines health system resilience and patient safety, further exacerbating inequities in access to quality care by widening the already poor HRH-to-patient ratios.[137]

Year	Nurses	Midwives	Doctors
2010	399	—	123
2011	356	14	100
2012	681	17	151
2013	1,208	—	—
2014	1,587	—	—
2015	2,459	400	213
2016	2,167	178	216
2017	2,450	179	235
2018	1,349	154	144
2019	1,379	33	162
2020	1,455	33	207
2021	1,082	57	113
Total	**16,572**	**1,065**	**1,664**

Table 1.4. Estimated total stock (production) of health workers in Burundi from 2010 until 2021. For each year, the table shows the total number of cadres produced nationally by category. **Source**: *Republic of Burundi. Plan Stratégique de Développement des Ressources Humaines pour la Santé, 2019 – 2023. Document de politique sanitaire. Ministère de la Santé Publique et de la Lutte contre le SIDA, République du Burundi, Bujumbura, Burundi 2017*.

1.10. Burundian health information system

Burundi's health information system (HIS) reform agenda has propelled from paper-based records to embedded electronic health data management, supported by a coalition of donors including Enabel, Gavi, UNICEF, and others.[138,139] Central to this shift is the hospital management information system (HMIS) implemented via the OpenClinic GA platform,[140] piloted in a representative mix of district, regional, and national hospitals beginning in 2015 to modernise hospital information and enable integrated recording of clinical, administrative, financial, pharmaceutical, laboratory, radiology, and health statistics data for decision-making.[138,141] By 2017, about three-

quarters of public hospitals had been computerised and the number of primary health facilities joining this digitalisation programme was growing rapidly. In 2023, it was estimated that about 90% of facilities nationwide were computerised.[141,142]

This progress follows earlier assessments that revealed weak data sources, limited data use, and quality concerns in a system historically dominated by paper records.[143-145] Despite meaningful gains, weaknesses in data source, incomplete data integration, and data dissemination gaps persist, underscoring the need for sustained financial and capacity development to maintain and scale digital hospital information across Burundi's health pyramid.[138,145] In addition to routine HMIS records, Burundi conducts routine biennial EmONC data monitoring targeted at designated EmONC facilities to assess their capacity for emergency obstetric and neonatal care, identify bottlenecks, and inform targeted improvement efforts.

1.11. Study aim and objectives

My research aims to provide empirical evidence on the structural and workforce challenges facing Burundi's EmONC network. It further examines using a set of scenarios how the country might prioritise workforce investments, considering more substantial and limited resource conditions, to improve maternal and newborn survival.

The first objective was to examine the capacity challenges facing Burundian EmONC facilities and to develop alternative investment proposals to improve their readiness paying particular attention to human resources, physical infrastructure, and capital equipment. Strengthening the 112 EmONC facilities is strategically sensible for Burundi because they manage about two-thirds of all obstetric complications amongst the 85% of deliveries currently taking place in health facilities.[146,147] Moreover, increasing EmONC facility capacity and performance could improve the overall functioning of EmONC referral systems. To achieve this objective, I used facility data on EmONC resources including staff availability to estimate resource gaps and drew on cost data to forecast the budget needed to address these deficits taking a government perspective for a five-year EmONC investment strategy. More specific details will be provided in Chapter 4.

The second objective concerned examining EmONC competence. Evidence highlights the need for sufficient and skilled delivery care professionals to deliver on the maternal and neonatal agenda,[148,149] and further underscores that quality care is only possible with competent health workers able to correctly perform salient clinical tasks.[150,151] Unfortunately, research has found that a significant proportion of qualified health workers specifically in LMICs have insufficient skills to offer correct care for most maternal and newborn complications.[151-154] Thus, understanding health worker competence in EmONC facilities is particularly helpful for countries like Burundi to inform actions and policy change. Additionally, given that the routine biennial EmONC training is expensive, it is important to assess its effectiveness in improving provider skills and determine whether the benefits warrant the investment. This was done using five EmONC clinical vignettes representing the most common maternal and newborn complications in Burundi and drew on the guide for health workers on the management of complications in pregnancy and childbirth jointly developed by WHO, UNFPA, and UNICEF.[155] Clinical vignettes are believed to be an effective and inexpensive approach in LMICs where routine chart documentation is often incomplete or absent.[156] Details about these vignettes, statistical analyses, and results are provided in Chapter 5.

The third objective aimed to identify priority EmONC facilities assuming that Burundi may not successfully mobilise the whole budget required to fully address identified resource deficits across the entire 112 EmONC facilities. Facing continued economic difficulties,[157] Burundian policymakers may struggle to mobilise the large amounts necessary for strengthening the entire EmONC network in the near term especially in the light of competing priorities including disease outbreaks.[158-162] This challenge is further exacerbated by the global reductions in development assistance, primarily resulting from the recent closure of USAID's overseas programmes. To achieve this objective, I built a facility prioritisation framework based on prevailing workloads, existing resources, and maternal mortality. The framework enabled me to identify a subset of EmONC facilities commonly characterised by high delivery workloads and greater numbers of complications that are very poorly staffed. These facilities I posit could be targeted for priority investment in the face of scarce resources. The facility prioritisation framework, statistical analyses, and results are provided in Chapter 6.

The fourth and final objective leveraged on findings from previous chapters with a focus on human resources and aimed to inform Burundian health policymakers of the likely costs and maternal health benefits of different EmONC workforce investment scenarios over the mid-term horizon from 2025 until 2030. Indeed, over the past two decades, Burundi has engaged in numerous strategic planning and resource allocation discussions in healthcare, driven by rising health risks and demands and budgetary pressures that are all undermined by an overall economic downturn.[11,163,164] Achieving the goal of ending preventable maternal mortality (EPMM)[165] and advancing health equity[166,167] requires greater political commitment to health reforms and the strategic redirection of limited resources; commitment that is often lacking in many LMICs.[168,169] To achieve this objective, I developed in collaboration with stakeholders four workforce investment scenarios and predicted using a decision tree the likely costs and maternal health benefits of each proposal over the 2025–2030 horizon. Findings from this objective, presented in Chapter 7, are intended to inform policy discussions involving stakeholders and development partners that support the Burundian EmONC programme.[51]

1.12. Rationale for engaging stakeholders: evidence-based decision making

Engaging stakeholders was essential for the success of my study because its primary aim was to generate empirical evidence to assist Burundian health policymakers and stakeholders in identifying resource requirements and allocating the limited EmONC resources. Indeed, healthcare systems worldwide regardless of their financing structures and organisational frameworks face resource constraints relative to competing priorities. As a result, priority-setting remains one of the most significant challenges for health policymakers.[170] Similar to many other LMICs, Burundi lacks sufficient empirical local evidence to guide policy decisions; its health planning relies on adopting global guidelines and recommendations or revisiting historical patterns. These approaches can be misleading, possibly reducing the overall efficiency.[171,172]

To demonstrate the above need for empirical evidence to assist Burundian decision makers more generally, I compare research publications from Burundi with its

neighbour countries. A mapping of available health research publications highlighted that Burundi has a severe shortage of empirical evidence with only 34 health publications over ten years from 2002 until 2011, most of which were authored by foreign researchers. In contrast, Rwanda contributed 205 health publications and Kenya produced a substantial 3004 health publications during the same period.[173] Furthermore, while Kenya and Rwanda registered 205 and 20 clinical trials respectively, Burundi did not conduct any such study to inform policy and practice.[173]

A more recent comprehensive study that mapped and assessed health sciences research capacity and production across all 54 African countries from 2008 until 2017 continued to reveal significant disparities in research infrastructure, funding, and scientific output across the continent with many francophone countries including Burundi notably lagging behind.[174] According to Table 1.5 for instance, Burundi's scientific performance remains markedly low compared to Rwanda and other countries in the region. We see that this country recorded only 23.09 publications per 1 million inhabitants which highlights the limited research production compared to other countries (e.g., Rwanda with 127.46 publications per 1 million population). Further, its number of first authors in scientific productions is equally low, indicating minimal local research capacity and lack of local leadership and ownership of research initiatives. Also, from 2007 until 2017, Burundi conducted just 1.81 trials per 1 million population, nearly eight times lower compared to Rwanda and more than 10 folds lower compared to Uganda and Kenya despite Burundi having a higher ratio of universities per 1 million population these two countries. Overall, Burundi considerably lags behind in research and development capacity, a situation that contributes to poorly informed health planning and decisions thus undermining the country's efforts to achieve UHC.[110]

Translating research evidence into policy and practice is only feasible if policymakers and stakeholders are actively involved in study design and conduct.[175-178] When stakeholders are adequately engaged, there is greater awareness of research findings and increased likelihood of their utilisation.[175,179] However, research intended to inform policy decisions and practice must also produce robust, credible, and acceptable findings including comprehensive evidence on the predicted costs and expected benefits as well as the complexities of proposed interventions.[180,181]

The above is the rationale for involving stakeholders from the design of my study throughout the implementation and dissemination phases, and for estimating the costs and benefits of workforce investment options to enable informed investment decisions.

	Number of publications per 1 million inhabitants	Number of first author publications per 1 million inhabitants	Number of trials per 1 million inhabitants	Number of universities per 1 million inhabitants
Burundi	23.09	6.37	1.81	0.86
Rwanda	127.46	45.14	8.14	0.92
Tanzania	138.85	56.99	7.79	0.40
Uganda	198.85	84.27	15.69	0.46
Kenya	294.79	125.27	13.19	1.03

Table 1.5. Comparison of health sciences research capacity and output in selected East African countries, from 2008 until 2017. **Source**: *Wenham C, Wouters O, Jones C, et al. Measuring health science research and development in Africa: mapping the available data. Health Research Policy and Systems 2021; 19(1): 142*.

Chapter 2.
Literature review and study frameworks

The literature review Chapter provides a backbone of my thesis conceptual framework and the analytical foundations. It contains the literature that informed the Methods, Results, and Discussion Chapters of this thesis.

In the first section, I present the frameworks that underpin my thesis, demonstrating how these frameworks informed the analytical trajectory. I begin the Chapter with the health system framework and its constituent building blocks, which serves as the structural lens for the thesis analysis. I then describe the WHO's QoC framework along with the Thanzi La Onse (TLO) framework. Together, these two models shape the conceptual architecture that guides the empirical work presented in this thesis.

The second strand focuses on established methods that informed the statistical framing of my Chapters 4 through 7. These methods comprise the Workload Indicators of Staffing Need (WISN) which enables to estimate staffing requirements based on observed workloads, the Lives Saved Tool (LiST) which helps to project the mortality reduction (impact) resulting from health investments such as workforce interventions, and the effective service coverage framework which is crucial for evaluating and improving healthcare systems by measuring the proportion of people who receive quality care that leads to a positive health outcome. Each framework is discussed in detail within this Chapter to justify its relevance and application.

In this literature review, I also examine alternative economic evaluation methodologies, arguing for the use of a decision-tree approach to model the comparative impact of health workforce investment options (details are presented later in Chapter 7).

This literature review Chapter concludes with my study's conceptual framework. The latter builds on elements from WHO QoC and the TLO frameworks (see Section 2.2) with the aim of addressing multiple building blocks of the health system framework (see Section 2.1) and the coverage cascade framework (see Section 2.3).

2.1. The health system framework

Central to my thesis is the pursuit of UHC through high-quality EmONC services. Within the broader UHC framework, WHO emphasises that all individuals should have access to the full range of quality health services they need across the life course; spanning health promotion, disease prevention, treatment, rehabilitation, and palliative care; delivered along the continuum of essential health services when and where they are needed, without financial hardship.[182-185] To advance the UHC agenda, WHO developed a comprehensive health system framework comprising six building blocks which, unlike disease-specific or narrower frameworks,[186-189] provides a robust basis for strengthening the overall health system to achieve more responsive, financially equitable, and most efficient health outcomes.[190] Evidence suggests that the WHO framework supports assessments of in-country healthcare performance,[191] elucidates the interactions between health reforms and health systems,[192] clarifies the implications of health sector reforms,[193] and appraises the status of health facilities[194] while also examining related health problems.[195] Figure 2.1 schematically presents the health system's six building blocks and demonstrates how investments in these pillars contribute to the broader health goals articulated in WHO's framework for aligning health systems with sustainable development aspirations.[182]

My thesis, which is conceptualised in Section 2.7, adapts the health system framework to the EmONC context and centres on five pillars namely (childbirth) service delivery, workforce, financing, medical products and technologies, and health information systems as highlighted in Figure 2.1 (red boxes). Specifically, I examine in Chapters 4 and 5 key infrastructure and technologies alongside human resources with attention to both the quantity (i.e., workforce deficits in Chapter 4) and quality (i.e., provider competence assessment in Chapter 5) of delivery care providers. In Chapter 6, I develop policy actionable proposals to maximise childbirth service delivery under resource constraints by prioritising a subset of facilities while in Chapter 7, I adopt an empirical approach to determine the appropriate scale of workforce investments and to estimate the anticipated impact of these investments. Thus, using the WHO's health systems framework, my thesis tries to investigate and develop strategies that could improve the

quality and safety of mothers and babies with the overarching aim of enhancing the overall quality and efficiency of childbirth care delivery.

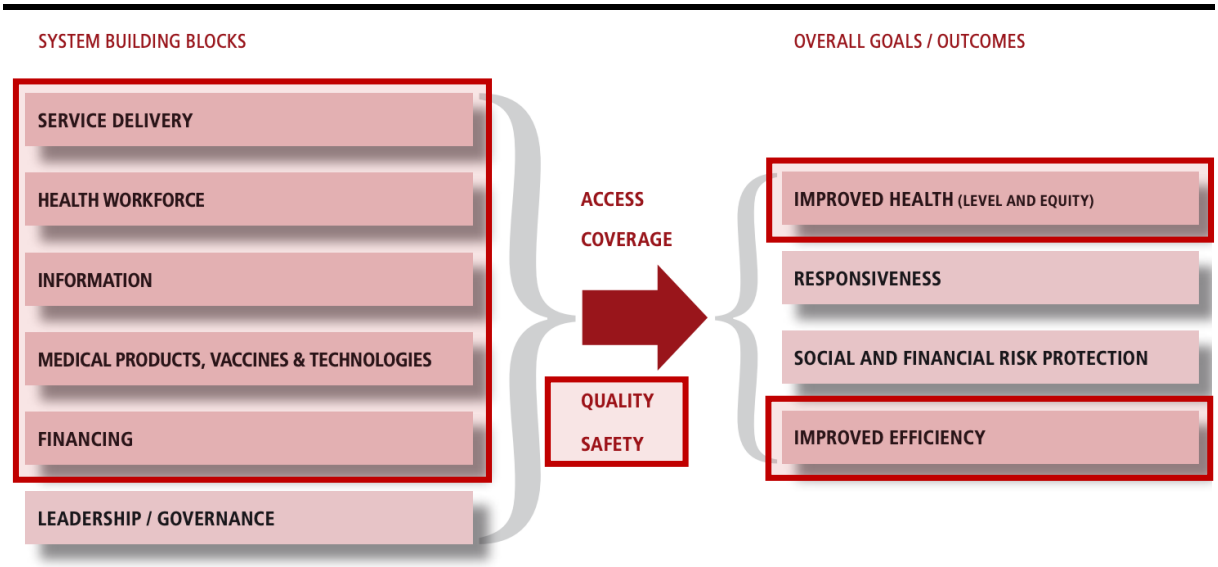


Figure 2.1 The WHO's health system framework illustrates how interventions targeting the WHO's health system building blocks translate into health system performance (outputs), improved health service utilisation (outcomes), and improved health (impact). **Source**: *World Health Organization. Everybody's Business; Strengthening health systems to improve health outcomes, WHO's Framework for Action. WHO, 2007, page 3.*

2.2. The WHO quality of care and the Thanzi La Onse frameworks

The goal of health system strengthening investments is to enhance the QoC, a concept originally articulated by Donabedian[196] and subsequently refined through successive iterations.[97,197,198] The current and widely used QoC framework which was developed by WHO is based on eight domains that articulate the structure and processes of care at health facility level and within the broader health system context.[97,98] The facility structure encompasses essential inputs needed to support the process of care.[97] In the context of EmONC, these inputs include maternity and neonatal care physical space, maternity and neonatology equipment, essential medicines and supplies, functioning laboratory and imaging services for maternal and newborn checks, an operational referral system particularly in BEmONC facilities, a supportive mechanism such as clinical guidelines for the management of maternal and newborn complications as well as adequate supervision, and a sufficient cadre of birth personnel with EmONC

competencies.[99,100] As conceptualised in Figure 2.2, QoC is defined as the extent to which health services for individuals and populations increase the likelihood of desired health outcomes. Such care must be effective (i.e., grounded in evidence-based interventions), safe (i.e., avoiding or minimising harm); and people-centred (i.e., responsive to individuals' preferences, needs, and values). Furthermore, health services that advance QoC must be timely (i.e., reducing waiting times and avoiding harmful delays), equitable (i.e., delivering uniform quality across gender, ethnicity, geographic location, and socio-economic status), integrated (i.e., providing a continuous range of services throughout the life course), and efficient (i.e., maximising the benefits of available resources and minimising waste).[99] As highlighted in Figure 2.2, my thesis explored five domains with the aim to achieve individual and facility-level outcomes.

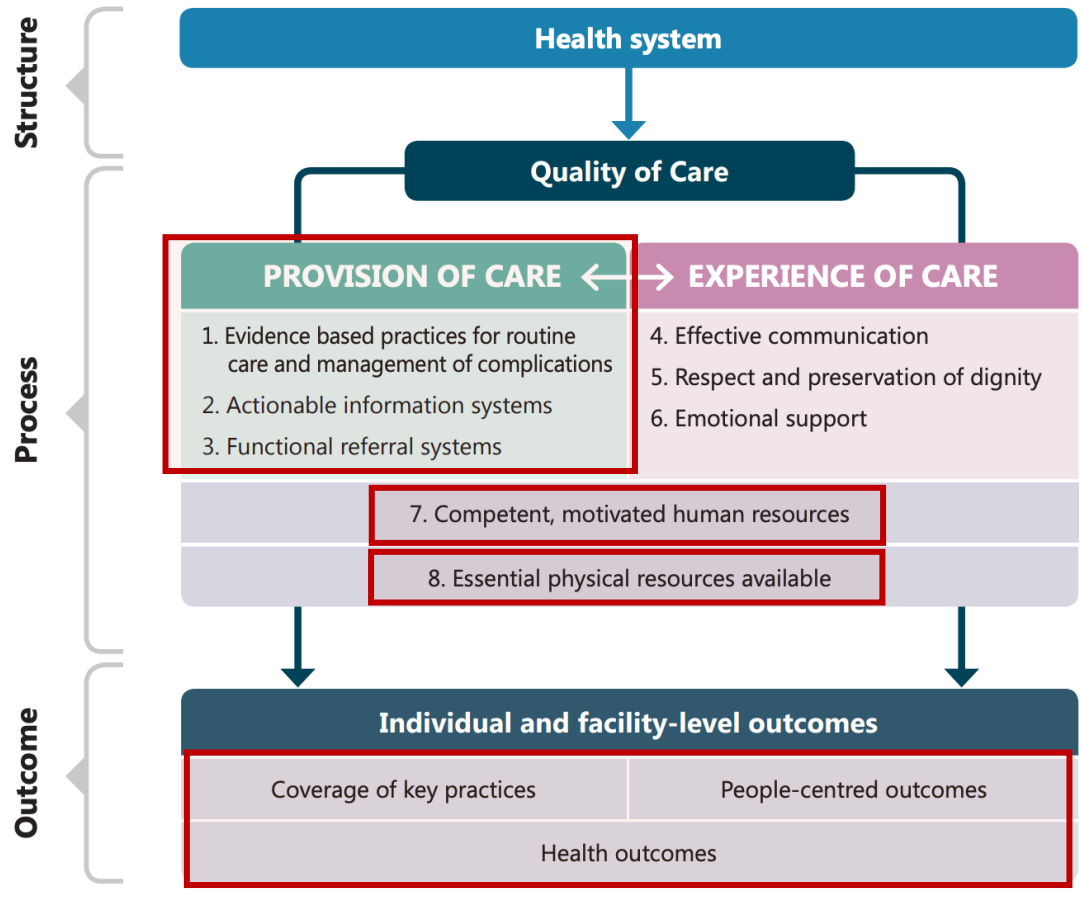


Figure 2.2 WHO framework for the quality of maternal and newborn health care. I highlight key domains that my thesis explored with red boxes. **Source**: *Standards for improving quality of maternal and newborn care in health facilities, 2016. World Health Organization. ISBN 978 92 4 151121 6 (NLM classification: WA 310), page 16.*

Furthermore, the Thanzi La Onse (TLO) (i.e., Health for All) model[199] provided a complementary framework that enriched my initial thesis conception in tandem with the WHO QoC framework. Developed through a collaboration of Kamuzu University of Health Sciences (Malawi), Imperial College London, University College London, and University of York (United Kingdom) and the East, Central and Southern Africa Health Community (ECSA-HC), the TLO model is a nationwide, individual-based simulation model that tracks a population and health events in Malawi across interconnected modules.[199] It comprises three primary module types: (i) core modules that capture fundamental processes such as demography, lifestyle, contraception, and health seeking behavior; (ii) disease modules that model disease dynamics, progression, and the impact of treatment versus non-treatment (e.g., tuberculosis, cancer); and (iii) a health system module that represents how health service capabilities are distributed relative to population needs, generated by the disease modules. The health system module operationalises public healthcare provision encompassing public and private facilities by specifying facility-level capacity in terms of health workforce time, availability of consumables and equipment, and bed capacity on a per-facility per-day basis. On the demand side, individual health seeking behavior is driven by symptoms, income, education, characteristics, and location, linking demand to supply through a daily simulation framework (Figure 2.3).[199-202]

Taken together, the WHO QoC framework and the TLO model provided a synergistic basis for the development of my thesis concept (see Section 2.7). The QoC framework clarifies the quality and safety dimensions of care namely effectiveness, safety, people-centredness, timeliness, equity, integration, and efficiency while the TLO model operationalises these concepts within a holistic, nationwide simulation that accounts for population dynamics, disease trajectories, and the spatial and temporal distribution of the health system capacity. This integration enables a more nuanced exploration of how quality improvement (QI) strategies in EmONC and maternal and newborn care cascade through health systems, affect service delivery and utilisation, and ultimately influence health outcomes at the population level.[199-202]

The conceptual model of my thesis is presented in Figure 2.6 and Figure 2.7 where I illustrate how QoC principles map onto the TLO model of health system performance and population health outcomes, tailored to the EmONC domain.

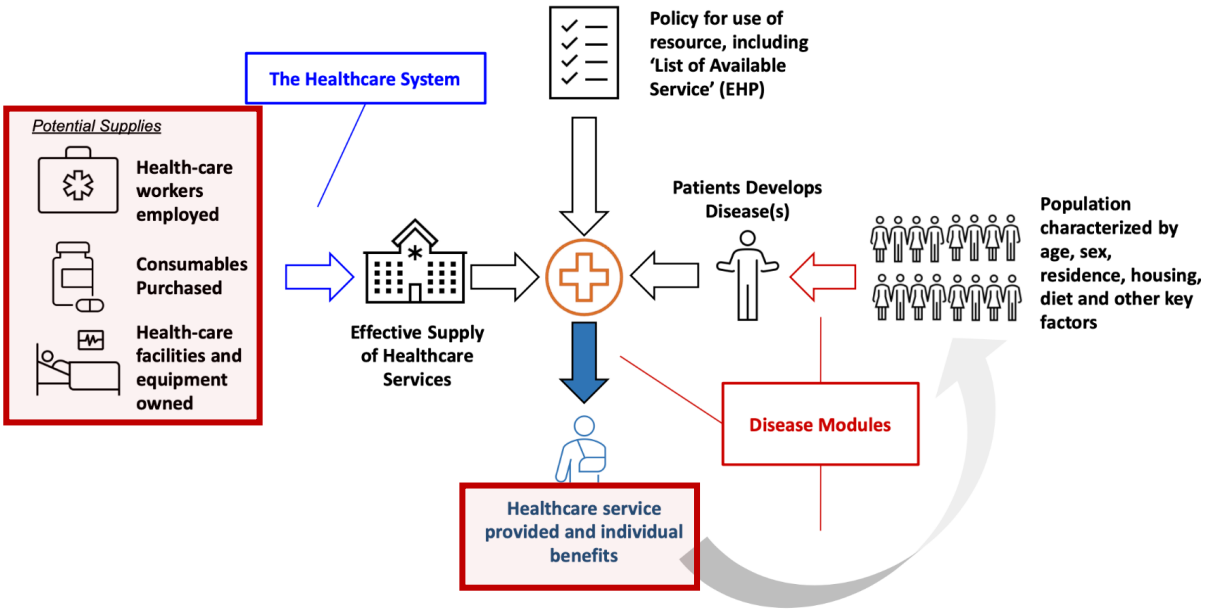


Figure 2.3 The Thanzi La Onse (Health For All) Model framework for the quality of maternal and newborn health care. I highlight key domains that my thesis explored with red boxes. **Source**: *Hallett, T. B., Mangal, T. D., Tamuri, A. U., Arinaminpathy, N., Cambiano, V., Chalkley, M., ... & Phillips, A. N. (2025). Estimates of resource use in the public-sector health-care system and the effect of strengthening health-care services in Malawi during 2015–19: a modelling study (Thanzi La Onse). The Lancet Global Health, 13(1), e28-e37.*

2.3. Effective EmONC service coverage cascade

Intervention coverage represents the proportion of individuals with a health care need who actually receive the specified service without accounting for the quality of the service received, which can lead to an overestimation of health benefits particularly when coverage is high but care is suboptimal.[203] Effective coverage extends this concept by incorporating the dimension of QoC into the measurement, recognising that the beneficial impact of an intervention depends on both access and whether it meets the standard, timely, and appropriate levels of quality.[203-205] To advance consensus on how to define and measure effective coverage for maternal, newborn, child, and adolescent

health and nutrition (MNCAHN), WHO and UNICEF convened a group of experts in 2019, the *Effective Coverage Think Tank Group*, who standardised the definition of effective coverage, identified robust measurement approaches, harmonised MNCAHN indicators, and outlined research priorities to advance the field.[204]

This work drew on findings from two prior reviews of effective coverage measures and applications,[205,206] which informed the recommendations and highlighted the need for a structured framework.[203] Central to this is the "health service effective coverage cascade" which outlines six sequential steps that capture different aspects of QoC.[203] These steps constitute a series of diminishing proportions of individuals from the total population in need of health care, those reaching a health care point, those accessing the specific service needed, and those receiving quality-standard services.[203]

Figure 2.5 is my effective coverage cascade adapted to EmONC context. It represents an analytical tool rather than a strict linear pathway and is intended to acknowledge that gaps can occur at multiple layers. I show in this Figure that a subset of pregnant women require EmONC services and that among those, only a portion may reach a facility with the necessary EmONC capabilities (i.e., service contact and readiness). When a facility offers EmONC services that meet quality standards, effective coverage is achieved, translating into improved maternal and neonatal outcomes.

This framework thus clarifies how EmONC service coverage cascades into real-world health gains and highlights where improvements in access, readiness, or quality are most needed to maximise the impact of health interventions.

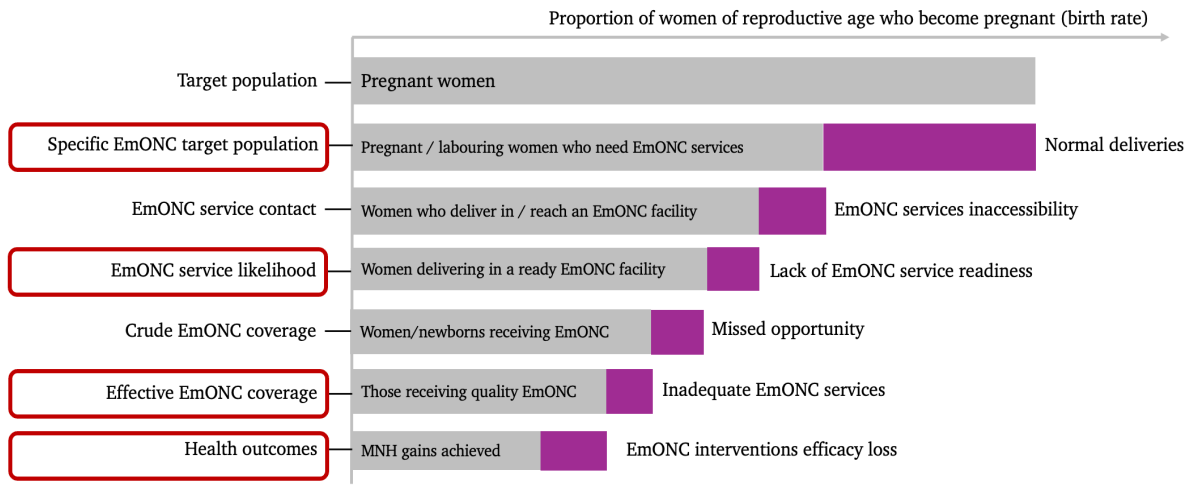


Figure 2.4 EmONC-adapted effective service coverage cascade. This figure shows how pregnant women transition between layers of care from those who need EmONC services until those who actually receive quality standard care. ***Source****: Marsh, A. D., Muzigaba, M., Diaz, T., Requejo, J., Jackson, D., Chou, D., ... & Soucat, A. (2020). Effective coverage measurement in maternal, newborn, child, and adolescent health and nutrition: progress, future prospects, and implications for quality health systems. The Lancet Global Health, 8(5), e730-e736.*

2.4. The workload indicators of staffing needs

Precious sections (e.g., Section 1.7) foreground the centrality of the health workforce to health system performance, demonstrating how staffing levels are fundamental for improving quality and equity in health service delivery. Traditional and widely used methods for estimating facility staffing requirements include population-to-staff ratios (e.g., number of doctors per 10,000 population) and fixed facility-based staffing standards (e.g., number of doctors and number of nurses for primary health facilities, first-level hospitals, second-level hospitals, etc.).[207,208] Unfortunately, these approaches fail to capture local variations in service demand, overlook the actual work performed by different cadres, and ignore differences in care complexity across settings.

Unlike traditional approaches, the WISN method bases staffing needs on actual work done and real professional standards, giving estimates that are specific to each facility and easier to use in decision making.[209] The WISN method originated in business and entered the health sector in the late 1990s but the original (health workforce) WISN manual developed by Peter Shipp and published by WHO in 1998[210] was regarded as inadequate by 2008; prompting subsequent revisions in 2010 and again in 2021, with

the 2021 updated WISN drawing on lessons from the coronavirus disease 2019 (Covid-19) pandemic to improve HRH management.[211] This method rests on the core idea that staffing needs should reflect the volume and mix of activities health workers perform. Each work component is assigned an activity time standard, which, when multiplied by the number and type of activities observed in a facility, yields the staffing requirements for that cadre. The method can be applied at multiple levels; from individual facilities to districts, provinces, and national aggregates, and it accommodates all facility types and departments, including specialised areas such as maternity units. By comparing actual staffing to calculated requirements, WISN produces explicit indicators of shortages or surpluses and can express workload pressure as a ration of actual to required staff. This enables priority setting and targeted interventions where they are most needed.[212,213]

One of the key merits of WISN is its accounting for local service demand variations and service delivery realities. Because staffing needs are derived from observed activities and their complexity, WISN captures differences in service scope, case mix, and patient demand that simple ratios overlook. This makes WISN particularly suitable for identifying inequities across facilities and geographic areas and for planning equity-focused staffing revisions. Moreover, WISN provides a flexible framework for planning under uncertainty by incorporating anticipated changes in workload such as expansions in service scope or shifts in population health needs to estimate future staffing requirements.[209,214,215]

The methodology also supports strategic human resource management in several concrete ways. First, WISN informs optimal staffing allocations by identifying where additional personnel are most needed and where reallocations or task-shifting could rebalance workloads. It enables careful consideration of whether to reduce some cadres, create new posts, or reassign tasks between cadres based on defined functions and overlap observed in the workload data. Second, WISN supports performance-based planning by benchmarking current professional performance against updated standards and quantifying the staffing implications of achieving higher performance levels. Third, the approach facilitates workforce forecasting by projecting the number of health workers required to deliver planned future services, rather than merely

cataloguing current workloads. Fourth, WISN can evaluate the impact of employment conditions on staffing requirements, such as changes in working hours, vacation policies, or in-service training, thereby linking human resources policies to numerical staffing outcomes.[211,212]

Beyond single cadres, WISN is adaptable to team-based service delivery and to cross-disciplinary care modelling. It can estimate staffing for services delivered by teams or by shared tasks across occupations, highlighting opportunities for staff sharing and improved resource allocation. Additionally, WISN can be used to develop or refine staffing norms at various facility types, clinics, health centres, or hospitals by generating estimates that establish standard requirements across broader categories while accommodating local variability.[211]

Thus, WISN represents a robust, evidence-based tool for health workforce planning. By tying staffing needs directly to actual workload and standardised performance criteria, it enables precise identification of gaps, informed prioritisation of investments, and rigorous forecasting for future demand. Its emphasis on local context, task feasibility, and systemwide implications makes it particularly well suited for guiding reforms aimed at improving service delivery quality, achieving efficiency, and promoting equitable access to care.[209,213,216,217]

2.5. The Lives Saved Tool

The Lives Saved Tool (LiST) is a mathematical, computer-based, and population-level simulation model designed to estimate how scaling up coverage of MNCH interventions affect mortality.[218,219] The model builds on *The Lancet Series* earlier work that estimated the effect of scaling up evidence-based interventions aimed to reduce child mortality,[220] neonatal mortality,[221] and to address nutrition determinants of maternal and child health.[222] LiST gained global attention, evolving into a free, publicly available software tool that health managers can use to quantify the potential impact of scaling up various interventions, thereby informing health planning and priority setting.[223-225] Specifically, LiST enables through its widely used component of Spectrum (i.e., a software package maintained by *Avenir Health*) to simulate the impact of scaling up or reconfiguring

evidence-based interventions and to translate coverage changes into estimates of "lives saved".[226] The integration of LiST with Spectrum software has helped to standardise assumptions, document provenance of inputs, and facilitate interoperability with other models used in health planning and monitoring.[227] Although LiST is a valuable tool for evaluating health impacts, it cannot explain why changes in health seeking behaviours occur. It rather indicates whether those changes were beneficial and has the ability to estimate the isolated impact of a single intervention amid other concurrent changes.[228]

Among the early prominent LiST users is Fischer Walker. He described in 2010 the guidelines developed by the Child Health Epidemiology Reference Group (CHERG) that were applied by scientists reviewing the effects of LiST interventions[229] and, in 2014, he leveraged this tool to model the independent impact of integrated community case management (iCCM) on child mortality[228] and the effect of childhood diarrheal interventions on reducing child mortality.[230] Within the field of MNCH, Bartlett et al. (2014) contributed a large-scale modelling study that estimated maternal and newborn deaths averted alongside the cost-effectiveness of scaling up midwifery interventions using LiST estimates from 58 LMICs.[231] Specifically, this study linked LiST interventions to midwifery and obstetric competencies, estimated intervention input costs, projected the numbers of maternal, fetal, and neonatal lives saved under different scales of coverage, and the cost per death averted.[231] A similar modelling study projected the number of deaths that would be averted by 2035 if coverage of midwifery interventions were scaled up in 88 countries that account for the vast majority of the world's maternal and neonatal deaths and stillbirths using four scenarios; a modest increase of 10% every 5 years, a substantial increase of 25% every 5 years, and universal coverage of these interventions (i.e., up to 95% coverage).[232] This study revealed that a substantial scale-up of these interventions could avert 41% of maternal deaths, 39% of neonatal deaths, and 26% of stillbirths; approximating 2.2 million lives saved per year. A modest increase could avert 22% and 23% maternal and neonatal deaths alongside 14% stillbirths (i.e., about 1.3 million lives saved per year) while the universal coverage scenario could avert 67%, 64%, and 65% of these deaths respectively, translating to 4.3 million lives saved per year.[232]

Projections from the *Midwifery 2* modelling study, using input data from 78 countries, found similar impacts. A modest 10% increase, a substantial 25% increase, and a universal (95%) scale-up of midwifery interventions delivered during the pregnancy life course including postpartum care and family planning were all associated with significant mortality declines, with the universal coverage attaining 61% reduction of maternal, fetal, and neonatal deaths.[233] This mortality decline would even cap 83% if MNH interventions were supplemented by family planning (FP) interventions.[233]

2.6. The impact of health investments: economic evaluation methods

Economic evidence in healthcare is increasingly utilised to inform policy and decision-making, especially in LMICs where optimising the allocation of the already scant resources is critically important.[234] There are five main types of economic evaluation in healthcare. They include cost-effectiveness analysis (CEA), cost-utility analysis (CUA), cost-benefit analysis (CBA), cost-minimisation analysis (CMA), and cost-consequence analysis (CCA). These methods are summarised in Table 2.1 below.[234-236]

Type	Description
Cost-effectiveness analysis	Cost-effectiveness analysis is a form of comparative economic analysis that evaluates two or more policy alternatives in terms of their relative costs and outcomes, where the outcomes are measured in a single natural unit (e.g. life-years gained, disease case averted etc.)
Cost-utility analysis	Cost-utility analysis (i.e., a specific type of cost-effectiveness analysis) is a form of comparative economic analysis that evaluates two or more policy alternatives in terms of their relative costs and outcomes, where the outcomes are expressed by a generic measure of health status that considers both the effect on mortality and morbidity e.g., quality-adjusted life-years (QALYs) and disability-adjusted life-years (DALYs)
Cost-benefit analysis	Cost-benefit analysis is a form of comparative economic analysis that evaluates two or more policy alternatives in terms of their relative costs and outcomes, where both the costs and outcomes are expressed in monetary terms. In principle, this analysis values the interventions relevant costs and outcomes based on the preferences of those affected (i.e., the individuals' willingness to pay)

Cost-minimisation analysis	Cost-minimisation analysis is a form of comparative economic analysis that compares the costs of two or more policy alternatives which are all assumed to have equivalent health effects
Cost-consequence analysis	Cost-consequence analysis is a form of comparative economic analysis that evaluates two or more policy alternatives in terms of their relative costs and outcomes, where the outcomes are not summarised in a single measure, and multiple outcomes of interest are reported

Table 2.1 Types of economic evaluation. **Source**: *Turner HC, Archer RA, Downey LE, et al. An Introduction to the Main Types of Economic Evaluations Used for Informing Priority Setting and Resource Allocation in Healthcare: Key Features, Uses, and Limitations. Front Public Health 2021; 9: 722927.*

In many cases, economic evaluations are conducted alongside randomised controlled trials (RCTs) using individual patient data to estimate the costs associated with different treatment options and assess their impact on both the quality and quantity of life saved or on morbidity and mortality averted.[237,238] However, when RCTs are not feasible, there exist several analytical frameworks that enable us to estimate and compare the costs and benefits of healthcare interventions.[236]

In my study, I explored these economic evaluation methods to identify the most appropriate approach for estimating the impact of potential EmONC investments in Burundi, with a particular focus on workforce investments. Since the objective was to evaluate how different workforce investment options could influence maternal and neonatal mortality, I found that a decision tree model was most suitable. This approach, implemented in Chapter 7, enables the modelling of a patient's progression from one health state to another under well-defined conditions.[239,240] Indeed, decision tree models are particularly useful when multiple alternative options are possible with uncertain outcomes and when choices follow clear, branching pathways.[241] In my situation, I developed various workforce investment alternatives with input from Burundian stakeholders and policymakers and used the decision tree model (see Figure 2.5) to estimate the costs and benefits of each option. Cost estimates were based on the workforce costing framework developed in Chapter 4 while benefits were measured by the number of maternal and neonatal lives saved per 100,000 deliveries, building on existing LiST estimates.

A detailed description of the decision tree methodology is provided in the dedicated section of Chapter 7. A decision tree model enables the calculation of health benefits in terms of utility-based measures such as quality-adjusted life years (QALYs) or disability-adjusted life years (DALYs), as well as estimating the number of deaths averted or lives saved.[242] One of the several advantages of the decision tree modelling approach is its ability to incorporate evidence from several sources such as evidence-based parameters rather than relying solely on a single source of information (e.g., a trial).[242] Finally, the decision tree framework permitted me to estimate the number of lives saved and deaths averted which were felt to be the most relevant outcomes in my situation.

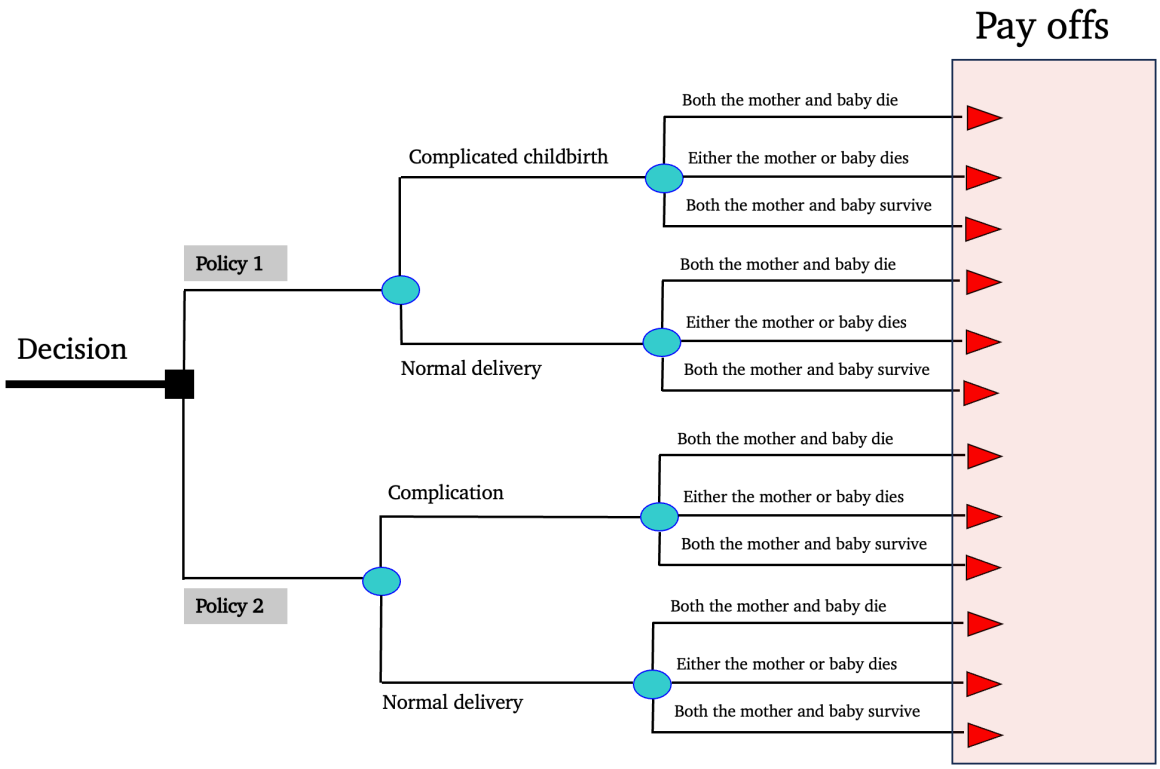


Figure 2.5 The decision tree model template (further details are provided in Chapter 7). This was employed to estimate the costs and impact of policy options aimed at strengthening Burundian EmONC facilities through a workforce investments. The yellow square represents a policy decision while the subsequent blue nodes denote chance events. Under any policy options, a complicated delivery is possible. For instance, under policy option 1 and following a complicated childbirth, there are three potential outcomes: both the mother and the baby survive, both die, or either the mother or the baby dies. Each pathway is assigned specific probability and cost estimates thus enabling the calculation of expected payoffs.

2.7. Study conceptual framework

My thesis, which is conceptualised in Figure 2.6 and Figure 2.7, draws on existing frameworks particularly the health systems strengthening framework (see Section 2.1), the effective service coverage framework (see Section 2.3), and the WHO QoC framework and The Thanzi La Onse model (see Section 2.2).[200] Combining elements of these frameworks, I illustrate in Figures 2.6 and 2.7 how inputs (i.e., resources), which the WHO QoC framework and more broadly the Thanzi La Onse model name as "the structure and potential supplies", combine with the process of care to produce high-quality care.[243,244] I adapted these frameworks specifically to EmONC services to depict the input, process, and outcome levels (Figure 2.7) capable of achieving QoC in the face of prevailing workloads. I will however acknowledge that the levels of inputs and workload depicted in Figure 2.7 are hypothetical and lack empirical thresholds. Therefore, this Figure simply aims to demonstrate the need of 'right balance' between available inputs and prevailing workloads to achieve quality care.

In the context of EmONC facilities, inputs include sufficient and competent delivery care professionals, physical infrastructure, equipment, laboratory services, and various amenities as detailed in Table 2.2. When these inputs are available and functional together with adequate human resources, they support the process of care which in turn leads to improved health outcomes. EmONC network facilities and services should be accessible geographically, available and affordable to users, and delivered with quality in accordance with established norms, standards, and clinical guidelines.[245]

Adaptation of The TLO model to EmONC alongside existing evidence[246,247] informed my study concept schematised in Figure 2.6 showing that the risk of obstetric complications depends on individual factors such as preexisting health conditions, which should be detected during ANC consultations. These conditions influence childbirth outcomes although further dependent on the facility readiness to provide quality care as depicted in Figure 2.7.

Human resources	Physical infrastructure	Equipment	Laboratory	Amenities
• Medical doctors • Midwives • Nurses	• Delivery rooms • Delivery tables • Maternity beds • Operating rooms • Incubators • Newborn care beds • Functioning ICU	• Delivery set • Adult resuscitation kit • Adult pulse oximeter • BP machine • Forceps or vacuum • Ultrasound machine • Foetal monitoring machine • Neonatal resuscitation kit • Neonatal pulse oximeter • Infant weighing scale • Phototherapy machine	• Beta hCG • Blood creatinine • Proteinuria • Full blood count • Blood typing • Blood matching • Malaria RTD • Malaria microscopy • Blood glucose • Urine glucose	• Electricity • Water tab • Public toilet • Ambulance

Table 2.2 Indicative list of EmONC essential inputs. These indicative context-relevant EmONC inputs were identified based on global EmONC guidelines (e.g., the WHO EmONC Handbook), the Burundian EmONC policy document, and benefited from stakeholder contributions.

Although not exhaustive, the essential EmONC resources listed in Table 2.2 provides a practical basic resource reference for Burundi's context. This list was compiled based on global and regional EmONC resource guidelines, standards, and recommendations, [72,248-252] the Burundian health policy documents especially the national EmONC normative guidelines defining resource requirements,[48,51] and benefited input from MNH experts comprising clinicians, researchers, donors, and policymakers with knowledgeable insights of EmONC within Burundi's context. Specifically, these experts reviewed the list of resources to ensure that it aligns with local needs (methodological details of identifying and estimating context-relevant EmONC resources are provided in Chapter 4).[253]

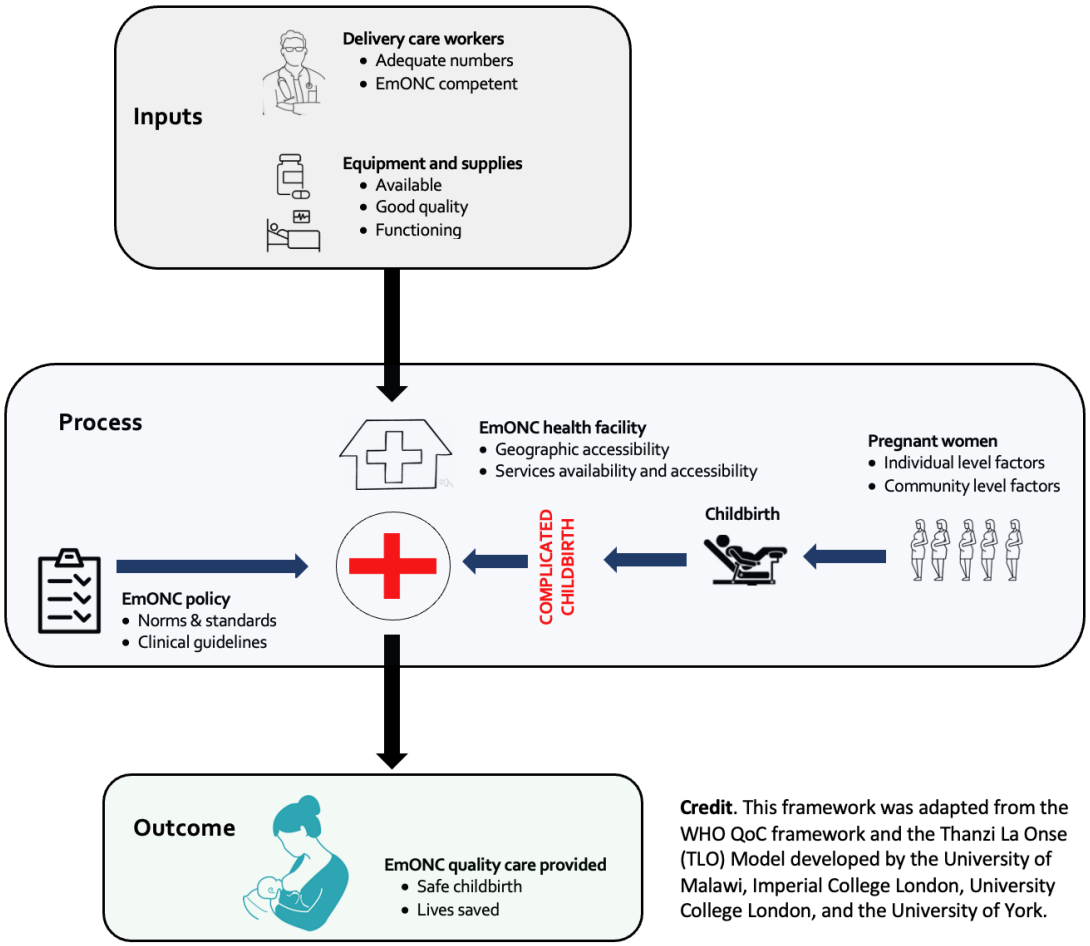


Figure 2.6 The study conceptual framework. This framework was adapted from the WHO QoC framework and the Thanzi La Onse (TLO) Model developed by the University of Malawi, Imperial College London (ICL), University College London (UCL), and the University of York. **Source**s: *Hallett TB et al. The Lancet Global Health 2025; 13(1): e28-e37* and *Turner HC, Archer RA, Downey LE, et al. An Introduction to the Main Types of Economic Evaluations Used for Informing Priority Setting and Resource Allocation in Healthcare: Key Features, Uses, and Limitations. Front Public Health 2021; 9: 722927.*

The red trapezoid in Figure 2.7 hypothetically represents the 'impossible' scenario typical to many LMICs where critical resource gaps, understaffing often also associated with underqualified or incompetent personnel, and overwhelming workloads make high-quality care unattainable. In contrast, the green trapezoid depicts environments likely to deliver quality care, where adequate infrastructure and supplies, sufficient numbers of well-trained personnel, and manageable caseloads create the prerequisite conditions for quality care. This framework indicates that ensuring the delivery of high-quality maternal and newborn care requires adequate and sufficient resources, the presence of well-trained, competent, and motivated workforce of delivery care

professionals such as nurses, midwives, and doctors who possess the necessary skills and knowledge to appropriately manage routine and emergency obstetric and neonatal complications. Furthermore, facilities should maintain manageable workloads for their staff implying that the volume of deliveries and related maternal and neonatal complications should be within the capacity of the available workforce.[254-256] Ultimately, the model shows that when resources are sufficient, staff properly trained and adequately competent, and workloads balanced with these resources, health workers can provide timely, safe, and respectful care which ultimately leads to better maternal and newborn health outcomes. Contrarily, shortages of resources and personnel or excessive high workloads compromise the quality of care, diminish patient satisfaction and safety, and increase the risk of adverse outcomes.

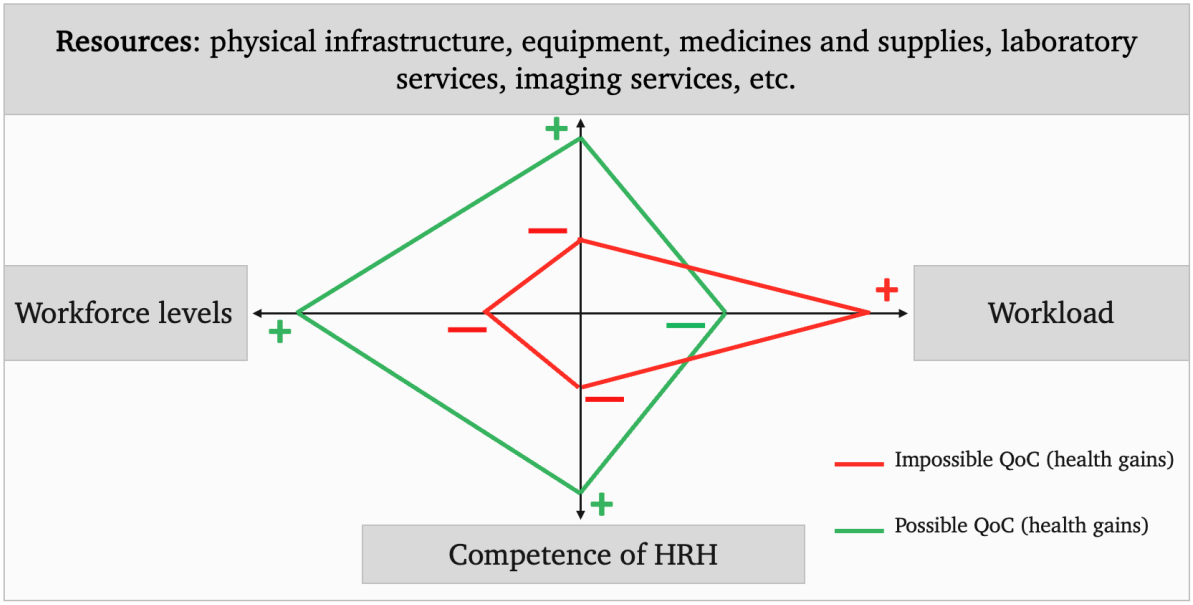


Figure 2.7 The relationships between resources, workload, and quality of care. This framework drew on existing evidence that emphasises that quality of care is possible if there are enough resources with sufficient and skilled human resources. However, the levels of inputs and workload depicted in this Figure are hypothetical and lack empirical thresholds. Therefore, the Figure simply aims to demonstrate the need of 'right balance' between available inputs and prevailing workloads to achieve quality care.

Chapter 3. Methods

This Chapter contains information from *Habonimana, D., Leckcivilize, A., Nicodemo, C., & English, M. (2022). Addressing the need for an appropriate skilled delivery care workforce in Burundi to support maternal and newborn health service delivery redesign (MNH-redesign): a sequential study protocol. Wellcome Open Research, 7, 196. (doi: 10.12688/wellcomeopenres.17937.2, see Appendix 2).*

I begin the Methods Chapter with the thesis structure to set the tone to further sections. Specifically, I present the research framework in Figure 3.1 outlining key pillars that form the thesis analyses, with each dataset contributing to a specific result. This is followed by a description of the study design, stakeholder engagement processes, the development of the research proposal and study tools, and ethical approvals obtained including securing necessary funding from the WHO Burundi country office. Regarding stakeholder engagement, I detail the roles and implications of the technical and steering committees which supported my study from its inception through the dissemination of findings. These committees will also play a crucial role in the upcoming policy discussions on EmONC investment options. The chapter proceeds with a comprehensive account of the development and validation of research tools, the training of data collectors, and the data collection process across EmONC facilities.

My study utilised a combination of primary and secondary data from EmONC facilities alongside direct interviews conducted with delivery care professionals and exit interviews of mothers following childbirth. Detailed descriptions of these data sources are provided in this chapter. The chapter concludes with an overview of our data analysis methods but more detailed explanations of each analytical approach will be presented in the subsequent Results Chapters. The sourcing and analysis of cost data are specifically described in a dedicated section in Chapter 4.

3.1. Thesis structure

I summarise in Figure 3.1 the core pillars of my thesis illustrating how each specific objective was systematically addressed through a multidisciplinary approach leveraging diverse data sources. Specifically, this Figure shows that my research integrated four distinct datasets, supplemented by a series of literature review focused on EmONC norms and guidelines alongside the WISN and LiST modelling approaches, insights from MNH experts, and stakeholder inputs.

Initially, I conducted an extensive document review to examine and critically appraise global and locally adopted EmONC norms and guidelines. This document analysis provided a foundational understanding of standard EmONC practices and benchmarks. To deepen this understanding, the review was complemented with an expert survey involving knowledgeable MNH professionals, comprising both Burundian nationals and international experts working in Burundi, who have specialised understanding of EmONC and the broader MNH domain within the country's context. The integration of these two information sources enabled me to develop EmONC resource benchmarks tailored to the context of Burundian EmONC facilities, ensuring relevance to local policy makers and, potentially, practicality.

Building on this foundation, I analysed primary and routine health facility data focusing on the availability and functionality of various physical resources, as well as human resources. Next, I compared these resources against the benchmarks established from the review and expert insights. This comparative analysis allowed me to identify resource gaps within each facility. To quantify the budgetary implications of these deficits, I costed the identified resource gaps using the expenses associated with each resource as well as the cost of EmONC training. As detailed in Section 1.11 and shown in Figure 3.1, this process directly addressed our **first specific objective** by integrating multiple data sources and stakeholder input to provide a first set of options to inform resource planning and budgeting. As part of this costing to enhance EmONC facility readiness, I further conducted an independent, detailed assessment of the skills and competence of delivery care personnel; addressing the **second specific objective**.

The third specific objective centred on facility prioritisation with a particular focus on allocation of human resources given that they are a major driver of service delivery costs. I examined staffing levels in conjunction with workload indicators namely the total number of deliveries alongside reported maternal and newborn complications, and maternal and newborn deaths. By comparing staffing against these workload metrics across facilities, I sought to identify facilities particularly experiencing the highest burdens combined with resource shortages, thereby pinpointing those that might be prioritised for targeted investments in the face of limited resources.

Finally, to refine my understanding of EmONC staffing needs, I employed the WISN methodology (see details in Section 2.4). Unlike the resource deficits assessments based on norms and expert opinion developed in the first specific objective, WISN uses facility data to calculate staffing gaps based on actual workloads thus employing a widely recognised empirical approach.[209,257] This method is promoted by WHO as a tool to inform policymakers on critical staffing decisions, health facility resource management, intervention-specific staffing requirements, skill-mix optimisation, and HRH policy revisions.[217,257-259] Moreover, I documented empirical evidence demonstrating the impact of midwifery interventions on reducing maternal mortality in LMICs based on LiST estimates (see Section 2.5), integrated this evidence with workforce needs derived from the WISN analysis and the insights from the previous three objectives, and developed the projected costs and benefits associated with various workforce investment scenarios (the **fourth specific objective**). These scenarios were developed and refined through stakeholder consultations enabling me to align practical considerations with evidence-based recommendations.

Overall and as illustrated in Figure 3.1, the entire doctoral process was underpinned and supported by active stakeholder engagement, thus ensuring that my findings are relevant, context-specific, and policy actionable. Unfortunately, the neonatal death and mother exit datasets did not contribute to the main DPhil analyses due to quality issues.

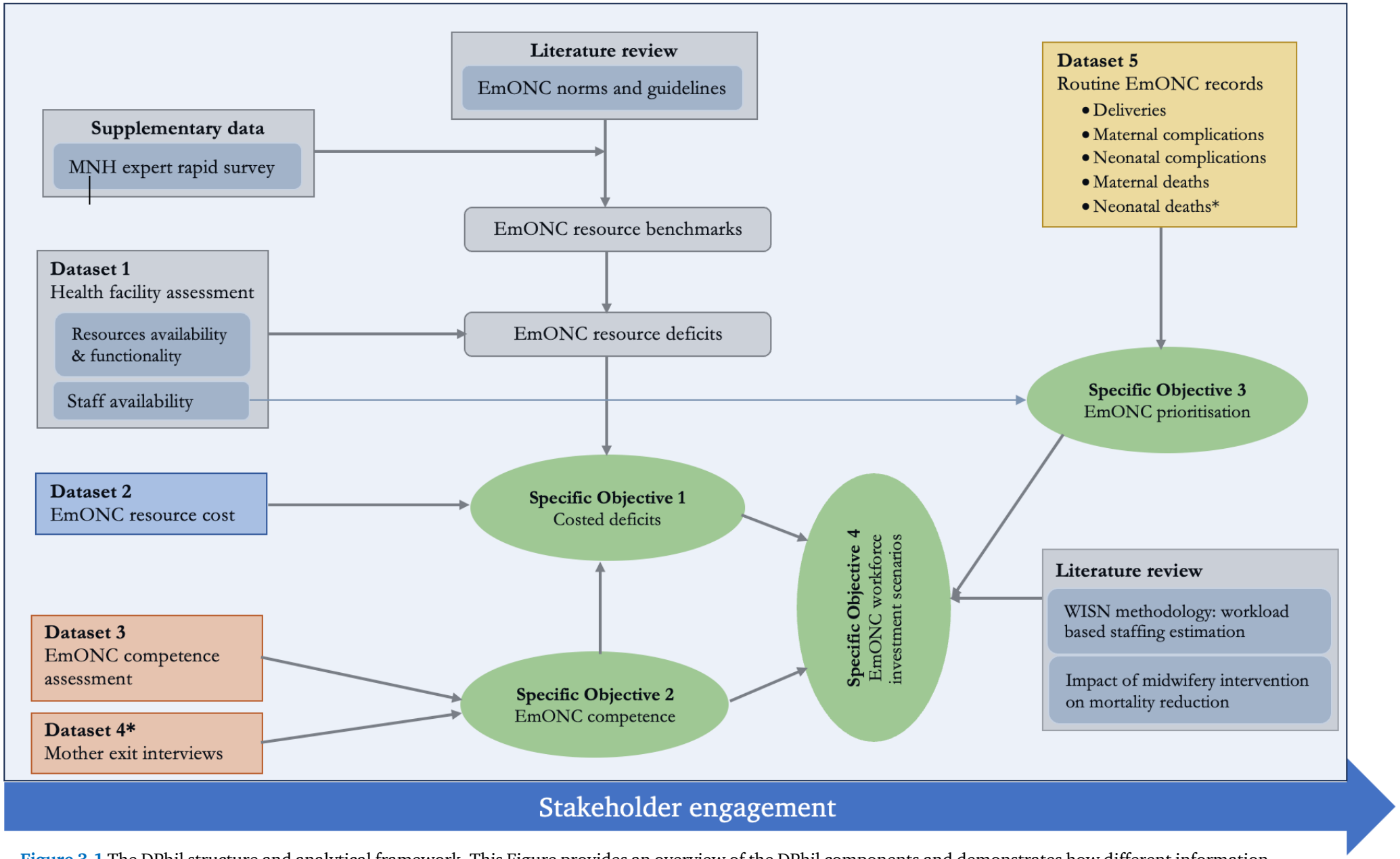


Figure 3.1 The DPhil structure and analytical framework. This Figure provides an overview of the DPhil components and demonstrates how different information sources (e.g., literature reviews, primary and routine data, and cost dataset) contributed to respond to each specific objective. Detailed data analyses are provided in the forthcoming Results Chapters. *Neonatal deaths and the mother exit datasets were not analysed due to quality issues (details are provided in Chapters 6 and 8).

3.2. Study design and setting

As schematised in Figure 3.1, I adopted a sequential study design employing multiple methods with each study phase systematically informing and feeding into the subsequent stage.[260] The process began with an extensive document review of both global and local EmONC policies and guidelines with particular emphasis on resource and staffing norms for BEmONC and CEmONC facilities in Burundi.

Drawing on the literature, I conducted a targeted rapid survey involving 12 MNH experts comprising clinicians, researchers, donors, and policymakers. These knowledgeable stakeholders contributed valuable insights regarding the types and quantities of resources, both human and material, needed to adequately equip Burundian BEmONC and CEmONC facilities. The expert inputs helped to refine resource standards tailored to the local context.

The third phase involved a comprehensive cross-sectional survey of all 112 designated EmONC facilities across Burundi. This survey aimed to collect primary data on staff availability, including the number and distribution of trained personnel, as well as the physical resources essential for quality maternal and newborn care. A complete inventory of these resources covering human resources, equipment, supplies, and infrastructure will be provided in the Chapter 4. Additionally, I collated routine maternity records covering the year 2021 to capture key service delivery indicators such as total deliveries, maternal and newborn complications, and maternal and newborn deaths.

In parallel, I assessed the competence of 311 delivery care providers using a specially designed EmONC competence examination tool which is comprehensively described in Section 3.5.3 and in Chapter 4. This assessment aimed to evaluate the skills and knowledge levels of frontline health workers namely nurses, midwives, and doctors performing maternal and newborn care in the study facilities.

Furthermore, I conducted structured exit surveys with 324 postpartum women to explore their lived experiences and perceptions of quality of care using Likert scales. These surveys drew on the WHO recommendations for intrapartum care aimed at

fostering a positive childbirth experience and other validated client experience interview tools focused on respectful maternity care (see Section 3.5.2).[261-263]

The final dataset aimed at estimating the costs associated with all EmONC resources, including human resources, physical infrastructure, and various equipment pertinent for maternal and newborn care. This final dataset was obtained from relevant departments within the MoH specifically the departments responsible for human resources, supply chain management, and infrastructure using government historical expenditure patterns, payrolls data, and the current financial planning and budgeting policies for the financial year 2022–2023. Throughout the study, I maintained active engagement with stakeholders and policymakers who were formally appointed by the MoH (see Figure 3.1). They provided ongoing support during the study design and implementation and further committed to disseminating findings and translating evidence into actionable policy and practice to improve the EmONC network and achieve better MNH outcomes.

3.3. Creation and engagement of study stakeholder committees

In Section 1.12, I outlined the rationale and justification for engaging stakeholders in our study. My thesis was therefore supported by three distinct stakeholder committees two of which were officially commissioned by the MoH and a third committee formed by myself in collaboration with my supervisors.

3.3.1. The permanent study committee

Prior to commencing the research, I consulted with the MoH to ensure that the project aligns with national health priorities, particularly those related to advancing the MNH agenda. This early engagement helped to ensure the study relevance to local needs and gain buy-in and support from key national MNH actors. I specifically collaborated with my supervisors to form and convene a dedicated, permanent stakeholder committee comprising seven experts representing diverse MNH stakeholders. This committee included representatives from the MoH namely the Deputy Minister of Health and the

Director of the RMNCAH programme, and representatives from the higher education and research institutions notably the medical school of the University of Burundi, key donors and development partners such as WHO and JICA, and service-delivery organisations represented by the Association Burundaise pour le Bien-Etre Familial (ABUBEF). The list of the study stakeholder committee members is provided in Supplemental material 2. These volunteer experts, chaired by the Permanent Secretary who also serves as the Deputy Minister of Health, offered continuous guidance throughout all phases of the study. Their contributions were particularly vital in shaping the study design, overseeing implementation, and validating preliminary findings thereby ensuring that our work remains aligned with national priorities and practical realities on the ground.

3.3.2. The technical and steering committees

To strengthen the study findings, the MoH emphasised the importance of a rigorous oversight and subsequently endorsed the establishment of two oversight bodies namely the technical committee responsible for refining the study protocol and data collection tools, guiding their deployment, and overseeing data collection procedures and the steering committee composed of senior policymakers and MNH experts responsible for validating the tools and reviewing the study findings.

The technical committee comprised 12 MNH technicians predominantly from the RMNCAH national health programme and representatives from UNFPA (see Supplemental material 3). This committee was primarily tasked with ensuring the technical robustness of the study proposal and instruments and their appropriate application during data collection. The steering committee comprised 11 senior MNH experts representing key stakeholders including the MoH Cabinet, development partners such as WHO, UNFPA, UNICEF, and JICA, and professional medical associations of Gynaecology and Obstetrics (AGOB) and Neonatology (ABUNE) (see Supplemental material 4). This high-level committee provided strategic oversight, validated the tools, provided data analytical orientations, and reviewed the study

preliminary findings to ensure that they respond to expectations and are relevant and aligned with national priorities.

3.4. Study proposals, ethical approvals and funding acquisition

Before drafting the research proposal, I presented to and discussed the study rationale and conceptual framework with key stakeholders in Burundi, including government officials from the MoH and those representing research institutions, donors and development partners, implementers, and healthcare providers. This consultation aimed to gather valuable input, ensure local relevance, and incorporate feedback to strengthen the study design and proposed methods.

Following these consultations, I prepared the full research proposal initially in English to meet the University of Oxford's requirements. To meet the official language requirements for Burundi, the proposal was professionally translated into French. The French version was submitted for ethical review and received approval from the Human Research Ethics Committee of the Faculty of Medicine at the University of Burundi (certificate number FM/CE/01/M/2022, see Supplemental material 5). Then, I obtained ethical clearance from the University of Oxford's Tropical Research Ethics Committee (OxTREC approval reference: 516-22, see Supplemental material 6). These two ethical approvals ensured that my study adheres to international standards pertinent to research that involves human beings and further supported my application for supplementary research funding from WHO in Burundi to cover data collection activities.

The field activities, which included conducting surveys across 112 EmONC facilities nationwide (see Supplemental material 1), abstraction of routine maternity records, administration of an EmONC competence examination to 311 delivery care providers and interviewing 324 postpartum mothers significantly exceeded the initial British Pound (GBP) £15,900 funding allocated to my DPhil study through the University of Oxford's Medical Research Council (MRC) doctoral scholarship. I estimated that an additional funding package amounting to US$ 60,0000 was needed. With official endorsement from the MoH and my study stakeholder committee (see Supplemental material 2), I successfully mobilised US$ 60,000.00 from WHO in Burundi. Together

with the Oxford DPhil research allowance, the WHO grant financed the training of data collectors and the subsequent fieldwork activities. This early stakeholder support including the endorsement of the MoH in securing WHO funding was an important milestone to demonstrate political engagement and commitment to our research. My study was therefore sufficiently funded to ensure comprehensive data collection and high-quality fieldwork, ultimately strengthening the robustness and validity of my research findings.

3.5. Survey tools development and validation

Initially, I developed a set of research instruments designed to collect comprehensive data for my study. These instruments included i) a facility data collection tool to gather detailed information on resources, staffing, and infrastructure, ii) a routine maternity records abstraction form to extract relevant clinical and service delivery data from existing records, iii) a client exit interview questionnaire to capture women's experiences and perceptions of care quality, and iv) an EmONC competence examination tool to assess the skills and knowledge levels of delivery care providers (relevant datasets are shown in Figure 3.1). These instruments drew on validated existing tools, established EmONC normative documents, and relevant guidelines to ensure reliability and contextual appropriateness.

I then submitted these draft instruments for review to the permanent study stakeholder committee for initial inputs. These tools were successively reviewed by the technical committee and further validated by the steering committee (see Section 3.5.5).

3.5.1. Health facility survey instruments

The literature offers a diverse array of health facility assessment tools explicitly designed to evaluate various dimensions of service delivery spanning service availability, readiness, and quality including tools specifically tailored to assessing maternal and newborn care.[264-270] These instruments generally encompass comprehensive assessments of facility requirements stratified by level of care, routine

obstetric and neonatal service provision, and the operational status of basic and comprehensive EmONC functions, among other services.[271]

In my study, I reviewed and synthesised key elements from several prominent global health facility assessment tools including the Averting Maternal Death and Disability (AMDD) EmONC Needs Assessments, the WHO Service Availability and Readiness Assessment (SARA), the JICA Health Facility Census (HFC), the MEASURE DHS Service Provision Assessment (SPA), the Child Survival Technical Support Project (CSTS+) Rapid Health Facility Assessment (R-HFA), the MEASURE Evaluation Facility Audit of Service Quality (FASQ), the WHO Service Availability Mapping (SAM), and the Quality Evidence for Health System Transformation (QuEST) tool.[264,269,272,273] The AMDD EmONC Needs Assessment toolkit which has been adopted and promoted by many users including WHO, UNFPA, and UNICEF [264,271,274] provides a robust framework for categorising facilities based on their functionality, classifying them into either functional BEmONC, functional CEmONC, or non-functional EmONC facility.[275,276] Building upon these existing methodologies, I developed a specialised survey instrument tailored to our context, designed to collect detailed primary data on key health system components including human resources, infrastructure, equipment, laboratory services, and essential amenities necessary for the provision of quality maternal and neonatal care. Detailed description of my health facility instrument has been published in my previous report[277] and is given in Chapter 4 and as Supplemental material 7.

3.5.2. Mother exit interview tool

The client exit interview questionnaire was structured into four main sections and was developed drawing on existing exit interview guidelines and best practices in research surrounding quality and respectful childbirth.[263] The first section focused on collecting socio-demographic information alongside pregnancy background and maternal health history. The second section aimed to examine the admission experience documenting the processes from arrival at the health facility until the first contact with a delivery care professional. This included capturing waiting times, the clarity of information provided upon arrival, and the perceived efficiency of the admission procedures. Such

data are critical for understanding potential delays and diagnosing bottlenecks that may impact quality care. The third section assessed mothers' satisfaction with intrapartum care encompassing multiple domains such as the effectiveness and clarity of communication during care, the presence and support of health care providers during labour, respectfulness and dignity in treatment, and the continuity of care throughout labour and delivery. This assessment aimed to gauge not only clinical quality but also the interpersonal and respectful aspects of care, which are essential for positive childbirth experiences. The final section of the mother exit interview tool explored mothers' satisfaction with postnatal services and the immediate newborn care. This section focused on aspects such as the quality of postpartum support, counselling received, and the newborn's care and feeding practices capturing therefore the overall experience and perceived quality of the continuum of care from admission through intrapartum, postpartum, and immediate neonatal care. The mother exit interview tool is provided as Supplemental material 8.

3.5.3. EmONC competence assessment tool

The EmONC competence assessment tool consisted of a set of five clinical vignettes each reflecting the most common maternal and newborn complications encountered in clinical practice. These vignettes were developed based on the guidelines provided by WHO, UNFPA, and UNICEF for health workers on the management of pregnancy and childbirth complications[155] which also serve as the foundation for Burundi's national EmONC training curriculum and define the core skillset required for EmONC providers. Each vignette presents a hypothetical clinical case that reflects real-world scenarios, including conditions such as postpartum haemorrhage, pre-eclampsia and eclampsia, obstructed labour, neonatal resuscitation, and the management of fever such as severe malaria. Each clinical case was accompanied by a battery of targeted questions designed to evaluate the respondent's clinical decision-making, problem-solving abilities, and adherence to recommended management protocols. This approach allows for a practical assessment of providers' capacity to recognise complications, prioritise interventions, and implement appropriate emergency responses. The development of this assessment tool involved close collaboration with MNH clinicians, researchers,

implementation partners, and professional associations to ensure local relevance and alignment with international standards. The tool is standardised and locally adaptable for evaluating the clinical competence of frontline delivery care providers in managing obstetric and neonatal emergencies thereby informing targeted training and capacity building efforts. The EmONC competence assessment tool is supplied as Supplemental material 9.

3.5.4. Cost data tool development

Additionally, I created an Excel spreadsheet that catalogues each EmONC resource (the detailed list of resources is presented in Chapter 4) alongside its associated unit cost in BIF. This resource list included essential physical commodities such as medical supplies, equipment, infrastructure, and laboratory services. Concerning human resources, I collected detailed data on salary scales for three main cadres specifically nurses, midwives, and doctors who are directly involved in maternal and newborn care as well as the average costs associated with EmONC training. This structured cost database enabled me to calculate cost estimates for resource procurement, personnel deployment, and training needs. The detailed methodology behind the classification of cost categories, the sources of cost data, and the procedures employed for data analysis are thoroughly described in Chapter 4.

3.5.5. Study tools review and validation

The above study instruments underwent a comprehensive review process in collaboration with the study technical committee (see Supplemental material 3). This review took place during a dedicated two-day retreat workshop held in Ngozi, a Northen, remote setting that enabled the conduct of focused discussions and consensus building (see Supplemental material 10). The tools review workshop was financially supported by the WHO grant. The primary objective of this review was to meticulously cross-examine each tool to ensure their alignment with national health standards and policies, while also verifying that the data collected would be accurate, relevant, and capable of identifying the bottlenecks hampering EmONC facilities. A special attention was given to the EmONC competence examination tool which was extensively revised

during this workshop with the expert guidance of two members of the technical committee who are experienced national EmONC trainers familiar with the content of the Burundian EmONC training curriculum and the expected skillset of delivery care providers. The final EmONC examination tool accurately reflected the practical competencies required in the local context and adhered to international best practices.

Following these technical revisions, I obtained formal validation of the tools from the study steering committee (see Supplemental material 11) confirming that the instruments were methodologically sound, contextually appropriate, and aligned with the study's objectives before their field implementation. These rigorous tools review and validation processes were crucial to developing a contextually appropriate study, promoting reliable data collection and as part of stakeholder engagement.

3.6. Training data collectors and fieldwork

The Burundi MoH recruited a team of 54 data collectors. These individuals were all medical doctors with prior EmONC training or hands-on maternity experience and previous experience conducting EmONC facility surveys or data collection for routine EmONC monitoring. Before training data collectors, an Information Technician (IT) expert commissioned by WHO and I collaboratively digitalised data collection tools into KoboCollect. I then trained data collectors over the course of 3 days. The training comprised comprehensive instructions on the use of the tools, standard operating procedures, and a peer-led pilot test to validate the data collection process. For operational purposes, data collectors were organised into 18 teams corresponding to the provinces of Burundi with each team comprising two data collectors and one supervisor. Each team collected data from EmONC facilities in their province of assignment over a period of 5 days from June 27 until July 01, 2022. Throughout data collection, I collaborated with the IT expert closely monitoring data quality daily and providing timely corrective feedback. Moreover, to facilitate real-time communication, I created a dedicated WhatsApp group enabling live chat and ongoing support.

Regarding cost data, I distributed electronically through email the pre-designed cost data collection tool to the relevant departments of the MoH particularly the units

responsible for human resources, supply chain management, and infrastructure. In order to obtain unitary costs of EmONC resources, I complemented this remote data collection with in-person visits to these departments to engage directly with relevant key informants with the purpose to validate cost information that were supplied to me through email. This dual data collection approach helped to maximise data accuracy which is vital for cost analysis.

3.7. Preliminary data analyses and report validation

Prior to conducting extensive data analyses integral to my doctoral research, I performed preliminary data explorations to assess data quality, identify initial patterns, and refine analytical strategies while addressing data quality issues. Additionally, I drafted a comprehensive country EmONC survey report which summarised key findings, data insights, and preliminary interpretations of the EmONC capacity gaps (see Appendix 1). This interim report was presented at a national validation and dissemination workshop held in Bujumbura bringing together diverse groups of stakeholders including senior MoH policymakers and representatives of development partners, academic researchers, professional medical associations, implementers, and provincial and district medical officers. Professor Mike English, my primary DPhil supervisor also attended the interim report validation and dissemination workshop in person during one of his field visits in Burundi. The presentation and validation of the interim report was a crucial milestone offering a greenlight to proceed with more extensive and detailed analyses that underpin my doctoral thesis. Discussions from this workshop were also useful as they informed subsequent data analytical approaches while ensuring that these forthcoming analyses are correctly aligned with the country priorities and policy needs.

3.8. DPhil data analyses

In this section, I provide an overview of the data analyses conducted as part of my doctoral research, structured to address each of the four main study objectives but detailed descriptions of the specific analytical methods and the statistical models employed for each objective will be elaborated in the corresponding Results Chapters to ensure that my research process and methods are clearer and can be replicated. All data analyses were performed using STATA 18 MP Parallel Edition software. A sample of STATA commands is supplemented as Appendix 7.

As outlined in previous sections, the overall analytical framework guiding my DPhil research is summarised in Figure 3.1. I began the DPhil by reviewing the Burundian national EmONC policy document alongside international and regional EmONC guidelines with an aim to extract evidence-based resource requirements for both basic and comprehensive EmONC facilities, serving as a foundational normative benchmark. To enrich and contextualise this normative framework, I conducted a rapid, targeted survey involving 12 Burundian MNH experts. Their insights yielded two supplementary resource benchmarks, one minimum and another maximum threshold, separately for both the basic and comprehensive EmONC facility types. Consequently, I developed three EmONC resource benchmarks; a normative benchmark based on established EmONC standards and two expert-derived benchmarks corresponding to the minimum and maximum thresholds. However, it is important to note that although these three benchmarks allowed for the quantification of resource deficits in each facility by comparing actual resource availability against each of these thresholds, none of them accounted for the reported workloads. Instead, they were solely based on the concept of a 'standard' BEmONC and CEmONC facility definition.

To fulfil my first study objective; quantifying and costing EmONC resource deficits; I used the first dataset (Figure 3.1) to estimate human and non-human resource deficits and assigned costs (drawing on the second dataset) to each identified resource gap, including expenses associated with EmONC training. This analysis produced facility- and system-level cost estimates necessary to close these deficits for each benchmark

and projected these needs over five years using standard approaches to adjust for market distortion and inflation (details are provided in Chapter 4).

Concurrently, I evaluated the EmONC competence of delivery care providers using the third dataset, addressing my second specific objective. Using the Item Response Theory (IRT) methodology, I analysed scores obtained on a five-vignette EmONC assessment exam thus allowing me to evaluate the competence levels among delivery care providers to inform thinking on EmONC training needs. The IRT also enabled me to identify specific gaps in skills and knowledge related to each clinical vignette (details are provided in Chapter 5).

To address the third specific objective, I developed a facility prioritisation framework that integrated routine service data especially delivery volumes, maternal and newborn complications, and maternal and neonatal mortality with data on existing human resources (fourth dataset). This framework enabled me to rank facilities based on workload-to-staff ratios thus identifying a subset of facilities disproportionally managing high volumes of deliveries and greater proportions of complications with comparatively limited human resources (see details in Chapter 6).

Finally, to move beyond Burundi's normative approach to workforce requirements, I reviewed the WISN methodology and conducted an extensive literature review of published studies to identify 'activity standards' for maternal and newborn care tasks. I applied these standards to facility-level workload data to calculate more precisely staffing shortfalls. Additionally, I synthesised empirical evidence from the studies that implemented the LiST methodology to estimate the potential impact of midwifery interventions on maternal mortality in LMICs. I integrated these findings into the cost analyses and developed together with stakeholders four investment scenarios for EmONC workforce expansion. Each workforce investment scenario was costed and evaluated using a Decision Tree model to project the potential reductions in maternal deaths (see details in Chapter 7).

Although I collected an extensive dataset on clients' satisfaction and lived experiences using the exit interview questionnaire (see Supplemental material 8), this dataset ultimately provided limited additional insights and was therefore excluded from this

doctoral thesis. In fact, preliminary analyses performed to fulfil the requirement of an EmONC report prior to conducting extensive DPhil analyses (see Appendix 1) revealed a consistent pattern of highly positive responses across respondents, regardless of the documented systematic capacity challenges within facilities. As discussed during the preliminary data validation workshop (see details in Section 3.7 and Appendix 1), this uniformity in self-reported high satisfaction levels suggests the presence of response bias, potentially attributable to the Hawthorne effect where respondents overstate their satisfaction to avoid potential negative repercussions or out of social desirability bias. Consequently, these limitations led me to excluding this dataset from analysis. Instead, I focused on other datasets that were robust and better aligned with the study's objectives of assessing service quality and systematic facility challenges. More insights concerning the above data quality issues of the exit interview are provided in Section 8.4 of the Discussion Chapter where I elucidate how and why such exit interview tools are prone to biases likely overestimating satisfaction with lived experiences and quality of care.

Chapter 4.
Examining and costing EmONC capacity gaps

This Chapter contains some of the content from *Habonimana, D., Leckcivilize, A., Nicodemo, C., Nzoriron kankuze, J. B., Ndacayisaba, A., Bishinga, A., ... & English, M. (2024). Eight years into the horizon of aspirational maternal and newborn health pledges: a nationwide cross-sectional exploration of the Burundian EmONC network capacity and budget deficits. BMJ open, 14(5), e083546 (doi: 10.1136/bmjopen-2023-083546). This publication is supplemented as Appendix 3.*

This third Chapter presents findings related to EmONC resource deficits and the budget required to address those identified gaps. It begins with a background to justify the need for these explorations and continues with the methods section which is divided into two main subsections. First, I develop the process of creating EmONC resource benchmarks which were used to examine EmONC resource deficits in each facility, then by facility type (i.e., BEmONC vs CEmONC), and further by health district and province. Second, I briefly remind the process of data collection emphasising on the data analytical framework particularly the costing methodology and various assumptions that guided the costing analysis. The Chapter continues with the results section followed by the discussion and conclusion. Key findings of this Chapter are highlighted in Box 4.1.

Box 4.1 Key findings from Chapter 4

Existing knowledge

- Although effective emergency obstetric and neonatal care (EmONC) has proved to avert three-fourths of maternal mortality, many African countries including Burundi failed to materialise these gains because their health systems continue to confront corrosive challenges that erode performance.

- In these countries, EmONC programme budgeting and resources allocation is fraught with fundamental inefficiencies and health policymakers and stakeholders lack solid grounds and empirical evidence for appropriate planning and optimal investment.

Methods

- I examined EmONC policy and guideline documents, consulted 12 maternal and newborn health experts, surveyed all 112 EmONC facilities, and collected cost data from various departments of the ministry of health and from the Burundian market. I developed three context-specific EmONC resource policy standards, estimated resource deficits by facility type and policy perspective, highlighted the distribution of these deficits at provincial level, and estimated the government budget needed to strengthen these EmONC facilities by policy alternative.

Key findings

- I found widespread and severe shortages of EmONC resources even when assessed against the minimum resource benchmark. Indeed, 95% of basic EmONC and all comprehensive EmONC facilities lack the minimum human resources and 90% of all EmONC facilities require additional major equipment and physical infrastructure. Specifically, Burundi needs 162 more medical doctors, 1005 midwives and nurses, 132 delivery rooms, 191 delivery tables, 678 and 156 maternity and newborn care beds, and 395 incubators to address EmONC resource deficits across the 112 facilities, linked to the highest policy scenario. This resource gap corresponds to an additional US$ 32.9 million budget requirements over the period of five years, amounting to approximately 5.96% total health budget increase annually.

Policy and practice implications

- Chapter 3 findings enabled Burundian policymakers and stakeholders to realise that the current EmONC policy and funding scheme cannot address the existing capacity problem. Further, these policymakers and stakeholders have understood the need to rethink and improve EmONC planning and budgeting along with resources allocation to enhance EmONC facility readiness.

4.1. Background

I showed in the introduction chapter that, despite political resolve,[48] Burundi continues to grapple with one of the world's highest maternal and newborn mortality rates[36,278,279] even though maternal mortality declined by 43% over the past 20 years from 874 (663–1134) maternal deaths per 100 000 live births in 2000 to 494 (353–694) deaths in 2020.[37] It is further projected that two Burundian women out of 100 continue to die of an obstetric complication particularly haemorrhage, infections, eclampsia, or unsafe abortion.[12]

Burundi began efforts to accelerate progress towards achieving maternal and newborn survival through investments in obstetric care particularly for emergency complications following the 2009 subregional workshop on MNH in francophone Africa.[280] Early initiatives included a series of EmONC needs assessments[281-284] and health facility mapping and capacity evaluations conducted around 2010.[285] Seven years later in 2017, the country formed the "maternity network" comprising 53 hospitals and 59 primary health facilities (see Supplemental material 1) designated as CEmONC and BEmONC facilities, respectively. Further, a specific policy supporting this EmONC programme was adopted, defining maternal and neonatal health goals and proposing how these facilities should be strengthened with appropriate resources to maximise their readiness to provide quality care for emergency obstetric and newborn complications.[50]

I also earlier informed that this EmONC programme is principally supported by major public health players including UNFPA, WHO, JICA, Pathfinder, and various local research and service delivery institutions who have pledged financial and technical commitments to support the country's efforts to advance the MNH agenda through EmONC services.[51] Concerning access, with 112 EmONC facilities for a country of 27,834 km^2 with approximately 13.6 million population in 2024, Burundi has until today surpassed the WHO recommendation of one CEmONC and four BEmONC facilities per 500,000 population.[52,53] Moreover, the Supplemental material 1 demonstrates that designated EmONC facilities are equitably distributed nationally to improve access with more than 97% of the population in many health districts

reportedly reaching an EmONC facility within two hours. Plus, user fees for pregnant women and children under five were removed in 2006 in efforts to promote UHC (see details in Section 1.2).[54] Routine maternity records indicate that these designated EmONC facilities perform nearly a third of all normal facility-based deliveries nationally and further manage approximately two-thirds of all obstetric complications.[50,51]

As shown in the study framework in Section 2.7, reduction of maternal and newborn mortality using the EmONC model of care requires that quality care is delivered. The current WHO QoC model, which underpins my thesis conceptual framework as demonstrated in Figure 2.6 and Figure 2.7 of the literature review and framework development chapter, is based on eight domains that encompass the structure and process of care at health facility level.[97,98] For EmONC facilities, the structure comprises essential resources such as physical infrastructure, maternity and neonatology equipment, essential medicines and supplies, and human resources.[97,99,100] Therefore, my QoC framework posits that appropriate resources (structure) supporting well delivered care (process) should result in better health outcomes.

However, given continued high maternal and newborn mortality recorded nationally even including within these 'special maternities' as shown in Figure 1.3 of the Introduction Chapter, I aimed in this third Chapter to conduct a comprehensive evaluation of the capacity challenges currently facing Burundian EmONC facilities to identify needs for further improvement and investment.[113] I specifically examined the availability and functionality of important EmONC resources (a comprehensive list of essential EmONC resources is provided in Table 4.1), gauging them against expected requirements to quantify key resource deficits. Further, I used the cost data to forecast the government budget required to close identified gaps paying particular attention to human resources, physical infrastructure, and capital equipment.

4.2. Methods

This methods section complements the general Methods Chapter by providing a detailed account of the specific procedures employed in developing the EmONC resource benchmarks, paying particular attention to the data analysis techniques. By elucidating these approaches, I aim to enable other researchers to replicate or adapt the methodology within similar contexts. Additionally, this Methods section briefly revisits the data collection process outlining the types of data collected to establish the context that underpins data analysis. Regarding the costing approach, I delineate the key assumptions underpinning the financial forecasts and describe the perspectives used to predict budget requirements. A particular attention is given to strategies employed to address and minimise cost uncertainties, especially considering the market imperfections characteristic of Burundian health sector thereby posing challenges to precise costing. The approach comprises the methods used to adjust cost estimates with the aim to enhance the robustness of these findings and ensure their relevance for policy planning and resource allocation.

4.2.1. Agreeing standards for EmONC resources

First, the MoH formed a permanent study stakeholder committee comprising seven members alongside two additional committees; the steering and technical committee comprising a total of 23 members representing policymakers (e.g., MoH cabinet, health programmes), researchers (e.g., university of Burundi), development partners (e.g., WHO, UNFPA, UNICEF, and JICA), implementers (e.g., Association Burundaise pour le Bien être Familial: ABUBEF), and medical professional associations (e.g., Burundian association of gynecology-obstetricians, Burundian association of neonatologists) (see Supplemental materials 2, 3 and 4). This multistakeholder structure was designed to ensure an inclusive representation, facilitate expert consultation, and promote shared ownership of the study findings. Second, to identify important EmONC resources relevant to Burundi's context, I reviewed existing national guidelines and policies and examined the literature.[72,248-252] This document review involved examining both international EmONC standards and local policy documents to extract Burundi-specific normative resource requirements for both basic and comprehensive EmONC facilities (see detailed information in Table 4.1).[48,51] Further, I supplemented these resource

normative findings with a targeted rapid expert survey involving 12 MNH experts comprising clinicians, researchers, donors, and policymakers who provided context relevant resource benchmarks. This combined approach ensured that the resource requirements used in this thesis were both evidence-based and tailored to the national context.

Category	Maternal health care	Newborn health care
Physical space*	Adequate number of delivery rooms, maternity beds, and delivery tables. CEmONC facilities should also have an operating room and a functioning intensive care unit (ICU).	Adequate number of newborn care beds and incubators. CEmONC facilities should also be able to offer neonatal ICU services.
Health services*	EmONC facilities should perform active management of the third stage of labour, breach deliveries, and provide VIH services.	EmONC facilities should provide newborn vaccination and Kangaroo Mother Care (KMC) services.
Equipment*	EmONC facilities should possess the delivery set, adult resuscitation kit, adult pulse oximeter, blood pressure machine, and forceps. CEmONC facilities should also have an ultrasound.	EmONC facilities should have a fetal monitoring machine, a neonatal or paediatric resuscitation kit and pulse oximeter, an infant weighing scale, and a phototherapy machine.
Drugs*	The following drugs should be available at all times: misoprostol, hydralazine, oxytocin, azithromycin, nifedipine, magnesium sulfate, ampicillin, gentamicin, metronidazole, and dexamethasone.	Sodium chloride and sodium gluconate eye drop should also be available at all times.
Cross-cutting resources		
Human resources*	Medical doctors, midwives, and nurses	
Supplies*	Oxygen, partograph, and clean and sterile gloves	
Communication	Computer, telephone, and access to internet	
Amenities	Toilets and water source in maternity common areas and electricity	
Guidelines	National protocol or guidelines for EmONC and essential neonatal care	
Referral system	Ambulance services	

Table 4.1 summarises important resources tailored to Burundian context needed to support the provision of quality EmONC services. The availability of these resources depends on facility type and level. (*) indicates core resources directly linked to obstetric and newborn care.

The above proposed resource criteria were reviewed and critically appraised through consultative discussions with the study stakeholders who 'sense-checked' and refined them to ensure that they are reasonable and feasible within the context of Burundi's healthcare system.[253] This iterative process allowed to refine resource standards which are aligned with local realities and operational capacities. From these stakeholder engagements and literature reviews, I developed three distinct EmONC resource

benchmarks; the normative threshold which is grounded in the existing Burundian health norms, and two expert-derived thresholds namely the minimum and maximum thresholds respectively reflecting the lower and upper bounds of resource adequacy based on expert opinion as summarised in Table 4.2. Finally, I used these alternative benchmarks to assess EmONC resource gaps and the subsequent budget needs.

EmONC physical and human resources	Burundian Health Norms		Expert suggested requirements	
	BEmONC normative needs	CEmONC normative needs	BEmONC (min, max) needs	CEmONC (min, max) needs
Delivery rooms	1	2	(1, 2)	(2, 3)
Delivery tables	2	4	(2, 3)	(3, 6)
Maternity beds	8	22	(6, 12)	(18, 26)
Operating rooms	n.a.	Unspecified	n.a.	(1, 2)
Incubators	Unspecified	Unspecified	(1, 2)	(3, 10)
Neonatal beds	Unspecified	Unspecified	(1,2)	(2, 4)
OBGYN	n.a.	Unspecified	n.a.	(0, 1)
Medical doctors	n.a.	1	n.a.	(1, 4)
Midwives	1	4	(1, 3)	(4, 5)
Nurses	2	9	(1, 4)	(4, 12)

Table 4.2 summarises the findings of the Burundian EmONC resource requirements development exercise. The table contains the explicit required EmONC resources from the Burundian health norms document and those suggested by MNH experts by facility type. Three EmONC resource benchmarks emerge: 1) the normative requirements, 2) the minimum expert suggested requirements, and 3) the maximum expert suggested requirements. 'n.a.' stands for 'not applicable' and 'unspecified' implies that information is not given in the Burundian EmONC normative document.

4.2.2. Facility survey design, participants, and data sources

As introduced in Section 3.6 of the general Methods Chapter, I conducted a cross-sectional survey of all the 112 designated EmONC facilities, interviewing health facility managers and maternity, laboratory, and supply chain head officers to document the availability and functionality of key resources as itemised in Table 4.1. These resources included delivery care professionals, physical infrastructure, delivery material and equipment, essential EmONC drugs and supplies, laboratory equipment, and maternity amenities. Particularly concerning delivery care professionals, I focused on those explicitly assigned to maternal health services such as midwives, nurses, and doctors excluding health workers primarily designated for other clinical functions (e.g., sick child/adult care) who might occasionally provide maternal care in a supplementary

capacity. Routine data for the year 2021 was obtained from the health facility information system and maternity records, capturing monthly data on the number of deliveries, obstetric and newborn complications, and birth outcomes. I trained 54 surveyors and grouped them into 18 teams corresponding to provinces and each team of two data collectors and one supervisor collected data across EmONC facilities in their respective province over a period of five days in June and July 2022 using a pre-designed digital survey instrument implemented into KoboCollect. Data collection was overseen by me, the principal investigator (PI), and an information technician (IT) consultant commissioned by WHO. We collaboratively monitored data quality daily and communicated with survey teams and all study stakeholders through a dedicated WhatsApp group.

4.2.3. Health facility survey data analysis

I categorised EmONC resources into five key domains: i) human resources, ii) physical infrastructure, iii) equipment, iv) laboratory, and v) ancillary amenities. I evaluated both the availability and operational functionality of each resource against the benchmarks; the expert minimum, normative, and expert maximum thresholds. This assessment was performed separately for each facility and by facility type, distinguishing between BEmONC and CEmONC facilities. I determined the proportion of facilities that have a complete set of resources using the three benchmarks and those with specific resource deficits. Further, I examined critical needs of major resources namely human resources, physical infrastructure and major equipment and aggregated facility-level deficits at district and provincial levels to demonstrate health districts and provinces where attention is most needed.

Additionally, with an aim to detect whether resource availability aligns with prevailing workloads, I explored at facility level the relationships between maternal and neonatal staffing (i.e., such as the presence and number of midwives and nurses) and annual delivery volumes alongside the frequency of maternal and neonatal complications. Even though deeper analyses of these relationships have been conducted in dedicated sections in Chapter 7, I did this initial analysis by visualising graphically using scatter plots the correlation between the presence of a midwife in BEmONC facilities and that

of a maternity-dedicated doctor in CEmONC facilities with deliveries and complication rates. These visual correlations were quickly complemented by bivariate correlation analyses to quantitatively examine associations between selected maternal and neonatal health metrics and EmONC resources. Health outcomes included facility-based MMR and NMR attributable to complications while predictors comprised the presence and number of doctors, midwives, and nurses and the availability of delivery rooms and delivery tables, maternal and neonatal beds, incubators, and intensive care units (ICU). These quantitative analyses aimed to elucidate the strength and significance of associations between resource levels and health outcomes to hint of the efficiency of resources allocation.

4.2.4. Cost data analysis and total EmONC programme budget forecast

Cost data of different EmONC resources was obtained from the MoH departments for human resources, supply chain management, and infrastructure using government historical expenditures and payrolls and the 2022–2023 financial planning and budgeting policy document. The purpose of the costing was to forecast the total budget needed to address the prevailing deficits of EmONC resources assessed against the three benchmarks described in Table 4.2 taking a government perspective for a five-year EmONC investment strategy. The five-year timeframe was chosen to meet the medium-term planning preference for Burundi and corresponds to the remaining timeframe of the SDGs agenda[286] and The Survive, Thrive, and Transform agenda[45] from 2025 until 2030. First, I categorised EmONC resources into capital and recurrent resources[287] and examined the quality and the nature of cost data. At this stage, I laid down reasonable assumptions underpinning these costs especially where there are considerable cost uncertainties.[236,288-290]

The Burundian market is fundamentally distorted by monopolistic and oligopolistic powers, negative externalities, currency fluctuations, unpredictable and unstable market tariffs due to frequent and sudden tax increases, and imperfect market information.[236,288,289] Therefore, the costs of all marketable resources such as medical equipment used in this study are believed to be flawed by market imperfections and cannot serve as true economic estimates. Contrary to marketable resources, salaries

and overheads are fixed expenditures less likely affected by market imperfections. To adjust for market inaccuracies linked to marketable resources, I used shadow prices to estimate economic financial values of different resources.[289,290] Shadow prices are an alternative costing approach used to estimate the social economic values when market prices are impaired by market inefficiencies.[289,290] For instance, economic costs of marketable resources were obtained by correcting their respective market tariffs using the prevailing black market for Burundian currency exchange rate: 1 US dollar officially exchanged at BIF 2,825 (2,810–2,840) against BIF 3,925 (3,850–4,000) black market value which corresponds to 38.94% (19.22%–40.85%) cost increase. In contexts where an official exchange rate does not reflect true economic costs, using the black market (shadow) rate helps align observed prices with social opportunity costs.[289,290] Shadow pricing adjusts for currency distortions, inflation, and market imperfections, providing a more realists valuation of traded inputs and capital goods.[290] By converting costs at market-consistent rate, the analysis avoids under or overestimating resource needs driven by official rates that may misprice imports, subsidies, or exchange risk. This approach enhances comparability across settings and supports informed policy decisions by synthesising marker realities with methodological standards for economic costing exercises.[290]

The budgetary costs of health professionals were calculated using monthly financial inclusive government expenditures by type of professional plus the average costs of onset and biennial EmONC in-service training and 3% annual salary growth as per the Burundian policies. The total government additional budget needs for an EmONC investment was obtained by aggregating annual cost subtotals for five years assuming zero discount rate (details in Table 4.3). To aid proper planning, I assumed that capital costs will wholly be spent in first investment year and EmONC training done in the first, third, and fifth years in line with the Burundian EmONC policy which indicates that delivery care providers in EmONC facilities should receive an onset EmONC training at job entry and another refresher training every other year. Final budgetary estimates were adjusted using the World Bank gross domestic product (GDP) mean deflator for Burundi over the previous five years from 2018 to 2022 (1.043). The yearly and total budgets were converted into US$ using the average exchange rate for the

second quarter of 2023. Forecasts were developed for each set of benchmark standards, existing Burundian policy norms and the expert minimum and maximum suggested requirements, to produce three budget alternatives for policy discussions.

Resources	**Costs adjustment and government budget calculation methods**
Human resources	The total government budget for delivery care professionals was calculated using monthly gross salaries, the annual salary growth rate, and the EmONC training cost. Firstly, I calculated the total annual government expenditure of each type of delivery care professional by summing their monthly gross salaries. Next, each annual gross expenditure was augmented by the annual salary growth rate (λ) to yield the gross expenditure for the subsequent year using **Equation 4.1**.

$$L_s = \sum_{i=1}^{n=3} \sum_{t=1}^{t=5} \lambda X_{(t-1)i} \qquad (4.1)$$

L_s *is the government total salaries for delivery care professionals (labour)*

X_i *corresponds to monthly gross salary of each type of delivery care professional*

$\sum_{i=1}^{n=1} X_{(t-1)1}$ *represents the annual gross salary of the preceding year for professional* 1. *For instance, the gross salary of a medical doctor in year 2 of employment is given by his gross salary in the first year of employment multiplied by* λ

$n = 3$ *implies three types of professionals: medical doctors, midwives, and nurses.*

$t = 5$ *means five years of investment which corresponds to the budget timeframe.*

Burundian EmONC guidelines prescribe that all delivery care professionals should receive an onset EmONC training and be recycled biennially until retirement. For instance, a medical doctor should be trained three times within the first 5 years of service and 16 times during 30 years of career. The final government expenditure on human resources was obtained by summing EmONC training costs T_s and salary costs L_s.

Buildings and all marketable resources	I corrected market tariffs using the black market currency exchange rate φ to yield shadow costs which are comparable to economic values and estimated the total budget of buildings and marketable resources using **Equation 4.2.** Furthermore, I used the World Bank GDP inflation rate for Burundi to adjust the costs of recurrent marketable resources. $C_T = \varphi \sum_{i=1}^{n} X_i$ *(4.2)* C_T *is the government total cost of acquisition of new buildings and of purchases* X_i *corresponds to individual market cost of item i* φ *corresponds to the black market correction factor 38.94% (37.01%–40 85%)* n *is the number of items (buildings and marketable resources).*
Non-marketable resources: overheads and maintenance costs	Non-marketable resources are not affected by market imperfections. The total government endowment size for a 5-year investment was therefore obtained by summing respective costs until five years.

Table 4.3 Detailed explanation of the costing methods of human, marketable, and non-marketable resources linked to EmONC facility needs in Burundi.

4.3. Results

4.3.1. Availability and distribution of EmONC physical resources

For clarity and conciseness, this section presents findings focused specifically on the assessment of EmONC resource deficits in relation to the expert minimum resource proposal, which represents the most basic and least demanding benchmark. Findings are summarised in Table 4.4 and reveal widespread and severe shortages of both physical infrastructure and essential maternity and neonatology equipment across both BEmONC and CEmONC facilities even when evaluated against this lowest benchmark. Concerning the physical infrastructure and capital equipment, only one out of 59 BEmONC facilities and seven out of 53 CEmONC facilities met the overall minimum

physical requirements. Specifically, approximately two-thirds of CEmONC facilities lack an additional delivery room and in general, deficiencies are evident across many facilities in key infrastructure components such as maternity and newborn care beds, incubators and resuscitation units. More than 90% of BEmONC facilities lack the minimal set of physical resources necessary to adequately provide care for newborns. While operating theatres are universally available in all CEmONC facilities, none of these facilities possesses a complete set of minimum required physical infrastructure and major equipment needed for comprehensive maternal and newborn care.

In contrast, non-capital equipment and laboratory resources such as delivery sets, blood pressure machines, forceps, foetal monitoring apparatus, and neonatal resuscitation kits are more commonly available in both types of EmONC facilities. Additionally, ultrasound and phototherapy machines are available in most CEmONC facilities although the effective utilisation of these technologies may be compromised if adequately trained and competent human resources such as medical doctors or skilled technicians are lacking, a pattern I detected in most EmONC facilities. Basic laboratory examinations indispensable for diagnosing the most frequent maternal and newborn complications or underlying maternal health conditions are often individually available but few BEmONC facilities (12%) can offer all basic laboratory services. Contrarily, Table 4.4 shows that over 95% of CEmONC facilities are capable of performing the full spectrum of essential laboratory diagnostics, reflecting their higher laboratory resource capacity over BEmONC facilities.

With respect to specific infrastructure and physical resource deficits presented in Table 4.5, operating rooms are exclusively recommended for CEmONC facilities, and their deficits are minimal. These minimal deficiencies remain relatively stable regardless of the policy benchmark applied. Nonetheless, Burundi exhibits a substantial need for additional maternity and newborn care beds, incubators, and delivery rooms. For instance, when compared to the least demanding benchmark (i.e., the expert minimum standards), EmONC facilities would require an expansion of approximately 35 additional delivery rooms along with 206 more maternity beds, 65 additional newborn care beds, and 78 more incubators to meet the basic resource adequacy. As the benchmarks increase to higher standards, the resource deficits become more

pronounced, as logically expected. For instance, to satisfy the expert maximum benchmark, the country would need a total of about 136 delivery rooms, 191 delivery tables, 678 maternity beds, 156 newborn care beds, and 395 incubators. These figures highlight the significant infrastructural gaps that persist across the EmONC network. Interestingly, the deficits of infrastructure and major physical resources do not display a clear pattern of geographic disparity and they appear to be widespread countrywide. Although provinces with a higher number of EmONC facilities tend to have larger absolute resource gaps, these deficits are proportional to the number of facilities which indicates that shortages are systemic rather than geographically localised. This therefore means that addressing identified infrastructural deficiencies would require broad, nationwide interventions rather than targeted provincial investment strategies.

	BEmONC (n = 59)		CEmONC (n = 53)	
	Expert minimum requirements	BEmONC meeting these requirements	Expert minimum requirements	CEmONC meeting these requirements
EmONC professionals	**All**	**3 (5.08)**	**All**	**0 (00.00)**
Medical doctors	n.a.	—	1 doctor	31 (58.49)
Midwives	1 midwife	5 (8.47)	4 midwives	9 (16.98)
Nurses	1 nurse	52 (88.14)	4 nurses	4 (7.55)
Physical infrastructure	**All**	**1 (1.69)**	**All**	**7 (13.21)**
Delivery rooms	1 room	59 (100.00)	2 rooms	18 (33.96)
Delivery tables	2 tables	57 (96.61)	3 tables	38 (71.70)
Maternity beds	6 beds	38 (64.41)	18 beds	33 (62.26)
Operating rooms	n.a.	—	1 room	53 (100.00)
Incubators	1 incubator	3 (5.08)	3 incubators	37 (69.81)
Newborn care beds	1 bed	5 (8.47)	2 beds	41 (77.36)
Functioning ICU	n.a.	—	Available	26 (49.06)
Equipment resources	**All**	**1 (1.69)**	**All**	**28 (52.83)**
Delivery set	Available	45 (76.27)	Available	53 (100.00)
Adult resuscitation kit	Available	38 (64.41)	Available	51 (96.23)
Adult pulse oximeter	Available	4 (6.78)	Available	51 (96.23)
BP machine	Available	58 (98.31)	Available	53 (100.00)
Forceps or vacuum	Available	46 (77.97)	Available	50 (94.34)
Ultrasound machine	n.a.	—	Available	52 (98.11)
Foetal monitoring machine	Available	52 (88.14)	Available	51 (96.23)
Neonatal resuscitation kit	Available	51 (86.44)	Available	53 (100.00)
Neonatal pulse oximeter	Available	3 (5.08)	Available	44 (83.02)
Infant weighing scale	Available	58 (98.31)	Available	53 (100.00)
Phototherapy machine	n.a.	—	Available	40 (75.47)
Laboratory resources	**All**	**7 (11.86)**	**All**	**45 (84.91)**
Beta hCG	Available	49 (83.05)	Available	50 (94.34)
Blood creatinine	Available	10 (16.95)	Available	53 (100.00)
Proteinuria	Available	38 (64.41)	Available	53 (100.00)
Full blood count	Available	9 (15.25)	Available	52 (98.11)
Blood typing & matching	Available	11 (18.64)	Available	53 (100.00)
Malaria rapid test	Available	57 (96.61)	Available	49 (92.45)
Malaria microscopy	Available	59 (100.00)	Available	53 (100.00)
Blood glucose	Available	53 (89.83)	Available	53 (100.00)
Urine glucose	Available	50 (84.75)	Available	52 (98.11)
Other amenities	**All**	**40 (67.80)**	**All**	**47 (88.68)**
Electricity	Available	56 (94.92)	Available	53 (100.00)
Water (maternity)	Available	50 (84.75)	Available	53 (100.00)
Public toilet (maternity)	Available	45 (76.27)	Available	49 (92.45)
Ambulance services	Available	56 (94.92)	Available	53 (100.00)

Table 4.4 summarises the expert minimum EmONC resources requirements and the number and proportion of facilities meeting these minimum requirements by type of facility. I excluded routine supplies such as essential medicines, transfusion blood, oxygen, clean and sterile gloves, and partographs since they do not account for the additional EmONC budget. n.a. stands for 'not applicable'.

4.3.2. Distribution of EmONC human resource deficits

With respect to human resources, I found critical shortages across all categories of EmONC professionals even when assessed against the lowest staffing benchmark. Nevertheless, achieving this minimal benchmark would still not achieve substantial improvement as this would simply make appropriate shift patterns that could sustain quality care impossible to achieve. For instance, under this lowest threshold, a typical BEmONC facility would be staffed with only one midwife and one nurse while a CEmONC facility would have only one doctor to cover 24-hour clinical care seven days, a plan that is unlikely to support and sustain continuous provision of safe and effective service delivery. I found that a professional midwife exists in only 5/59 (approximately 9%) BEmONC facilities, although often one generally qualified nurse is present. In the case of CEmONC facilities, only 9 (approximately 17%) have the recommended minimum of four midwives. Importantly, 22 (42%) of these CEmONC facilities do not have a medical doctor to perform caesarean sections or oversee advanced obstetric and neonatal care. On the whole, the findings indicate that 95% of BEmONC facilities do not meet the minimum requirement of having at least one midwife and one nurse, and none of the CEmONC hospitals meets the lowest benchmark threshold of one medical doctor, four midwives, and four nurses (results are detailed in Table 4.4).

In terms of human resource gaps and with respect to the lowest benchmark (expert minimum requirements) summarised in Table 4.5, Burundi requires 22 more medical doctors and 277 additional midwives and nurses to meet the minimum staffing standards across all facilities. When applying the existing national norms as a benchmark, the deficits of midwives and nurses double, highlighting the substantial human resource shortfalls. Under the higher, expert maximum benchmark which indicates that a CEmONC facility should be staffed with at least 4 doctors, 5 midwives and 12 nurses, the additional staffing needs escalates dramatically with an estimated staff requirement of 162 medical doctors and approximately one thousand midwives and nurses. With reference to the latter, the majority of provinces would need more than 10 medical doctors and between 40 and 80 midwives and nurses to attain these higher standards. Once again, provinces with fewer EmONC facilities have lower but likely proportionate human resource deficits.

Province	BEmONC facilities	CEmONC facilities	Number of deliveries in year 2021	EmONC professional deficits					Capital EmONC resource deficits														
				Medical doctors		Midwives and nurses			Delivery rooms		Delivery tables			Maternity beds			Theatre rooms	Incubators			Newborn care beds			ICU
				Minimum and norms	Expert maximum	Expert minimum	Burundian norms	Expert maximum	Minimum and norms	Expert maximum	Expert minimum	Burundian norms	Expert maximum	Expert minimum	Burundian norms	Expert maximum	Burundian norms or expert maximum	Expert minimum	Burundian norms	Expert maximum	Expert minimum	Burundian norms	Expert maximum	Either scenario
Cankuzo	1	2	3,551	0	5	8	18	30	1	4	0	2	6	3	13	25	1	1	14	14	1	4	4	2
Bururi	1	3	6,319	0	8	16	32	48	3	7	1	4	10	5	7	11	1	1	21	21	0	1	1	1
Mwaro	2	2	6,349	1	7	14	26	42	2	6	3	5	11	24	34	47	1	3	18	18	2	6	6	2
Makamba	4	2	6,733	2	8	10	22	45	2	8	0	1	9	10	18	41	2	4	19	19	3	9	9	2
Muramvya	2	2	7,223	1	7	13	25	41	2	6	0	2	7	11	21	37	0	3	18	18	1	2	2	0
Rumonge	4	1	8,204	0	2	6	15	35	1	6	0	1	14	15	23	42	0	3	13	13	3	7	7	1
Bujumbura city	1	6	8,735	4	19	11	24	49	0	2	0	0	8	0	0	4	1	6	25	25	1	5	5	1
Karusi	4	2	8,743	1	6	9	20	42	1	6	1	2	8	1	7	19	0	3	18	18	4	10	10	1
Rutana	2	3	8,877	2	11	16	32	52	2	7	0	2	9	14	24	38	1	2	22	22	4	8	8	2
Cibitoke	2	4	9,604	3	15	17	38	60	4	10	2	5	14	27	39	57	1	4	32	32	3	9	9	2
Ruyigi	2	3	9,904	2	11	17	34	54	2	6	1	2	6	5	17	35	2	4	26	26	2	7	7	3
Bujumbura R.	3	3	10,099	0	7	15	33	57	2	8	2	4	13	1	5	19	0	6	30	30	4	10	10	0
Bubanza	3	3	11,464	1	10	12	28	46	2	8	1	3	10	16	24	39	0	5	24	24	5	11	11	3
Kirundo	7	2	11,579	0	5	19	36	72	2	10	1	2	11	29	45	76	0	10	24	24	8	16	16	2
Kayanza	5	3	11,963	1	9	22	41	72	3	11	1	4	13	9	15	26	2	5	21	21	5	12	12	3
Muyinga	6	3	13,058	2	11	19	40	76	3	11	1	2	13	11	25	49	0	6	22	22	8	17	17	2
Gitega	4	6	13,349	2	15	38	72	112	1	9	1	2	14	10	28	60	2	3	22	22	3	6	6	3
Ngozi	6	3	15,065	0	6	15	36	72	2	11	2	4	15	15	27	53	1	9	26	26	8	16	16	2
Total	**59**	**53**	**170,819**	**22**	**162**	**277**	**572**	**1,005**	**35**	**136**	**17**	**47**	**191**	**206**	**372**	**678**	**15**	**78**	**395**	**395**	**65**	**156**	**156**	**32**

Table 4.5 summarises the deficits of EmONC professionals and capital resources by province and benchmark option. Often, two or all benchmarks recommend equal EmONC resource quantities and are combined.

4.3.3. Relationships between EmONC professionals and workloads

Based on the 2021 EmONC records, BEmONC facilities performed between 493 and 2431 (median 1365) deliveries and managed from 77 to 1748 (median 805) maternal complications and 15 to 670 (median 215) newborn complications. CEmONC facilities performed relatively more deliveries and handled more complications; between 331 and 3737 (median 1622) deliveries, 149 and 2385 (median 876) maternal complications, and between 29 and 816 (median 247) newborn complications. I expected a positive relationship between EmONC professionals (with midwives and nurses counted together) assigned to EmONC services and the annual number of deliveries, but Figure 4.1 does not support such a relationship. Five BEmONC facilities and two CEmONC facilities were found to have no EmONC specific midwife or nurse.

Figure 4.1a demonstrates that in some BEmONC facilities, 2000 or more annual deliveries take place in particularly understaffed facilities with fewer than three midwives and nurses combined. Two facilities without either professional dedicated to EmONC services performed more deliveries in 2021 than some facilities staffed with four or five midwives and nurses. In fact, four facilities with ten or more midwives and nurses performed half the number of deliveries compared to many understaffed facilities. With regard to reported case-mix as expected, facilities performing more deliveries tend to report caring for more women with complications. But this is an inconsistent relationship as is the proportion of women with a reported complication. As noted above higher workloads and thus higher numbers of women with complications are not necessarily receiving care in facilities with higher numbers of staff.

CEmONC facilities show similar patterns seen in Figure 4.1b. In the large majority, there is a major shortage of midwives and nurses. Data show that about 90% of deliveries take place in facilities staffed with fewer than six midwives and nurses and that the number of complications increases with deliveries. Furthermore, only one medical doctor is assigned to delivery care in 18 (34%) CEmONC facilities with annual deliveries in this subset of facilities varying from 702 to 3737. Meanwhile, Figure 4.1b shows that in CEmONC facilities with three or 4 medical doctors, the annual number

of deliveries reported ranges between 1215 to 2223. One CEmONC facility which reportedly performed 624 deliveries in 2021 does not have either EmONC professional and another CEmONC facility has four medical doctors without a midwife or nurse assigned to maternity services.

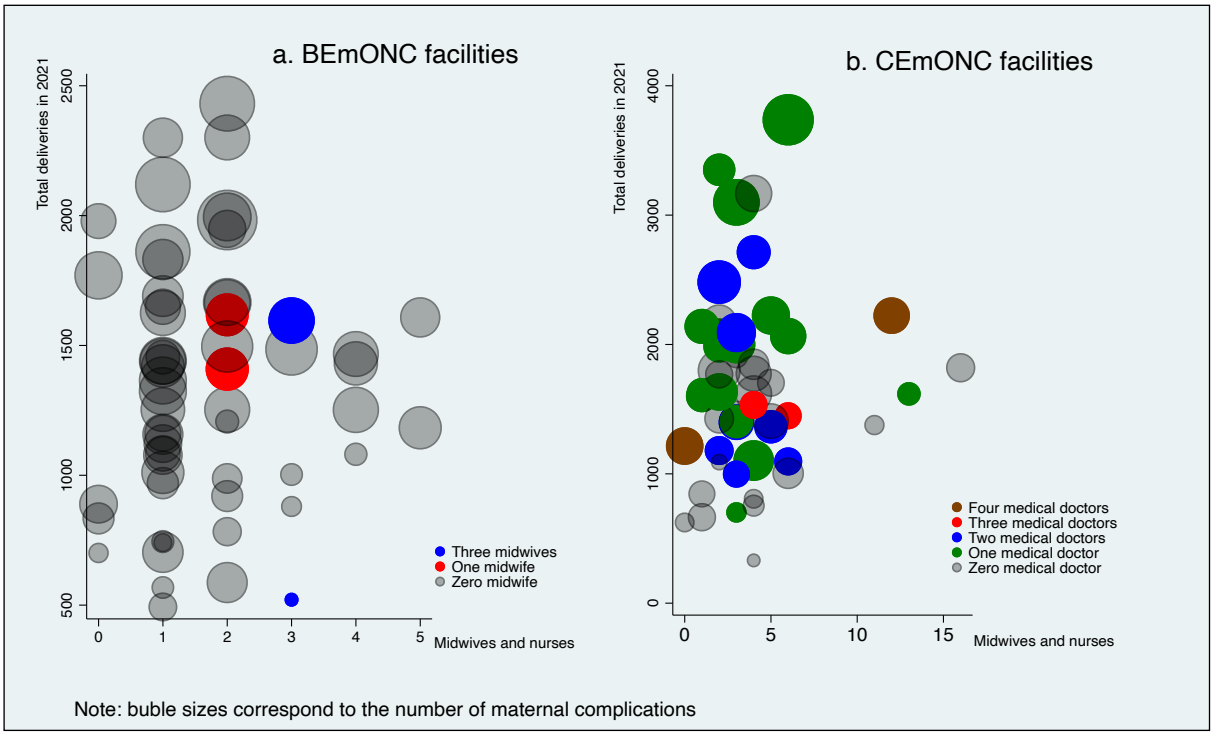


Figure 4.1 Relationships between EmONC delivery care professionals and workloads. Bubble sizes correspond to the number of maternal complications. Health workers examined in this Figure are those dedicated specifically to maternity care, excluding general providers who may also cover adult or pediatric care.

Finally, the results of the bivariate analyses detected interesting but predominantly weak and statistically non-significant correlations between maternal and newborn health outcomes and the availability of infrastructure and physical EmONC resources. For instance, there were predominantly negative relationships, though generally weak or moderate, between the number of delivery rooms, delivery tables, and maternity beds, and the rates of maternal and neonatal deaths due to complications. These correlation coefficients typically ranged between 0.1 and 0.5 indicating only non-statistically significant and modest associations. Detailed correlations are summarised in Table 4.6.

	All EmONC facilities			BEmONC facilities			CEmONC facilities		
	Maternal deaths*	Maternal deaths due to complications*	Neonatal deaths due to complications*	Maternal deaths*	Maternal deaths due to complications*	Neonatal deaths due to complications*	Maternal deaths*	Maternal deaths due to complications*	Neonatal deaths due to complications*
Medical doctors							–0.02	–0.14	0.04
Midwives and nurses	–0.04	0.04	–0.08	–0.09	–0.07	–0.11	–0.06	+0.01	–0.12
Delivery rooms	–0.17	–0.13	–0.17	**–0.36**	**–0.32**	**–0.49**	–0.15	–0.13	–0.14
Delivery tables	–0.16	–0.14	**–0.20***	**–0.31**	**–0.29**	**–0.37**	–0.16	–0.16	–0.21
Maternity beds	–0.13	–0.06		–0.25	**–0.27**			–0.14	
Newborn care beds			–0.09			–0.07			–0.19
Incubators							–0.12	–0.14	–0.22
Functional ICU							–0.07	–0.16	–0.24

Table 4.6 summarises overall correlations between outcomes and selected EmONC resources and by facility type. Maternal deaths represent facility-based maternal mortality ratio obtained by dividing maternal deaths by the total number of deliveries multiplied by 100,000. Maternal deaths due to complications are ratios of maternal deaths due complications divided by the total number of maternal complications. Neonatal deaths due to complications were calculated similarly using neonatal complications. Significant correlations are in bold and highlighted with a star. Coefficients (r) < |0.3| denote weak correlation, those between |0.3| and |0.5| translate moderate relationships, while r > |0.5| correspond to strong relationships.

4.3.4. EmONC programme budget estimates

Findings of the EmONC programme budget forecast are summarised in Table 4.7. Overall, Burundi needs an estimated US$ 13.6 million over a five-year period to implement an EmONC investment strategy aligned with the lowest benchmark. This would translate to an average annual increase of 2.46% in the total health budget, excluding costs related to routine supplies (e.g., drugs, transfusion blood, sterile and clean gloves, partographs), maintenance (e.g., buildings, equipment, ambulance), and overheads (e.g., other operational expenses). The corresponding budgets required to address EmONC resource deficits in relation to the normative and the expert maximum benchmarks are significantly higher, amounting to approximately US$ 20.6 and 32.9 million respectively. These budgets approximate 3.75% and 5.96% average increases of the total health budget annually for a period of five years. Human resources alone

account for 37% of the total additional budget, capital investment for 25%, and other recurrent resources which comprise EmONC equipment and laboratory needs account for 38%. Exceptionally, EmONC training involves expensive logistics with historical expenditures revealing that training one professional costs approximately US$ 8,131.99 (see Supplemental material 12).

Assuming that all capital investments are made in year one (e.g., in 2025/2026) and that EmONC training sessions are conducted as per the Burundian strategy (e.g., after recruitment and every two years), Burundi would commit 45% of the total additional budget to the first year and stretch the remaining balance over the next four years with higher expenditures occurring in the third and fifth years due to in-service EmONC training. In the second and fourth year, the country would invest between US$ 1.5 and 3.5 million corresponding to the minimum and the maximum benchmark scenarios. Annual budget estimates are provided in Table 4.8.

	Human and capital resources			Other resources	
	Expert minimum	Normative standards	Expert maximum		
Human resources	**13,634,945,433.93**	**26,838,568,556.24**	**54,090,410,713.60**	**1,404,314,982.29**	**Equipment**
Medical doctor	1,236,967,112.30	1,236,967,112.30	9,108,576,008.78	9,628,407.08	Delivery set
Midwives & nurses	12,397,978,321.62	25,601,601,443.93	44,981,834,704.81	2,876,017.70	Adult resuscitation kit
Capital resources	**9,262,666,548.67**	**15,072,566,867.26**	**21,112,620,849.56**	1,000,353.98	Neonatal resuscitation kit
Delivery rooms	1,604,734,513.27	1,604,734,513.27	6,235,539,823.01	53,643,982.30	Foetal monitoring machine
Delivery tables	56,450,530.97	156,069,115.04	634,238,318.58	234,805.31	Infant weighing scale
Maternity beds	626,805,132.74	1,131,900,530.97	2,062,980,000.00	53,338,318.58	Ultrasound machine
Operating rooms	¾	916,991,150.44	916,991,150.44	88,503,539.82	Phototherapy machine
Incubators	1,028,447,256.64	5,208,162,389.38	5,208,162,389.38	139,271,504.42	Blood pressure machine
Neonatal beds	77,485,752.21	185,965,805.31	185,965,805.31	847,299,823.01	Forceps
Intensive care unit	5,868,743,362.83	5,868,743,362.83	5,868,743,362.83	123,710,442.48	Adult pulse oximeter
				84,807,787.61	Neonatal pulse oximeter
				12,459,742,300.89	**Laboratory exams**
				840,297,345.13	Beta hCG
				420,148,672.57	Proteinuria
				1,307,129,203.54	Blood typing & matching
				8,402,973,451.33	Malaria rapid test
				835,629,026.55	Blood glucose
				653,564,601.77	Urine glucose
Total budget	**22,897,611,982.60**	**41,911,135,423.49**	**75,203,031,563.15**	**13,864,057,283.18**	
Budget BIF	36,761,669,265.78	55,775,192,706.67	89,067,088,846.33		
Budget US$*	**13,555,935.44**	**20,567,208.36**	**32,843,658.37**		

Table 4.7 summarises the total government budget for a five-year EmONC investment strategy by benchmark scenario. Supplies, maintenance, and overheads costs are routine expenditures and are explicitly excluded from the total additional EmONC investment budget needs. However, these costs are important as the government must bear in mind that EmONC facilities will continue to require these investments regularly commensurate with inflation and growth in demand for delivery services. *1 BIF = US$ 0.00035361709

	Year 1 budget	Year 2 budget	Year 3 budget	Year 4 budget	Year 5 budget	Total Budget
Human resources						
Expert minimum	3,348,480,000.00	1,601,114,400.00	3,443,147,832.00	1,698,622,266.96	3,543,580,934.97	13,634,945,433.93
Burundian norms	6,605,280,000.00	3,132,518,400.00	6,790,493,952.00	3,323,288,770.56	6,986,987,433.68	26,838,568,556.24
Expert maximum	13,233,600,000.00	6,418,548,000.00	13,613,104,440.00	6,809,437,573.20	14,015,720,700.40	54,090,410,713.60
Capital resources						
Expert minimum	9,262,666,548.67	-	-	-	-	9,262,666,548.67
Burundian norms	15,072,566,867.26	-	-	-	-	15,072,566,867.26
Expert maximum	21,112,620,849.56	-	-	-	-	21,112,620,849.56
Other needs						
Equipment	1,404,314,982.29					1,404,314,982.29
Laboratory exam	2,491,948,460.18	2,491,948,460.18	2,491,948,460.18	2,491,948,460.18	2,491,948,460.18	12,459,742,300.89
Total budget BIF						
Expert minimum	16,507,409,991.14	4,093,062,860.18	5,935,096,292.18	4,190,570,727.14	6,035,529,395.15	36,761,669,265.78
Burundian norms	25,574,110,309.72	5,624,466,860.18	9,282,442,412.18	5,815,237,230.74	9,478,935,893.85	55,775,192,706.67
Expert maximum	38,242,484,292.03	8,910,496,460.18	16,105,052,900.18	9,301,386,033.38	16,507,669,160.57	89,067,088,846.33
Total budget US$						
Expert minimum	6,087,138.82	1,509,324.71	2,188,578.04	1,545,280.92	2,225,612.94	13,555,935.44
Burundian norms	9,430,501.80	2,074,032.85	3,422,918.29	2,144,379.79	3,495,375.63	20,567,208.36
Expert maximum	14,101,988.80	3,285,762.51	5,938,768.88	3,429,903.79	6,087,234.39	32,843,658.37

Table 4.8 summarises annual budget needs by policy scenario. (*) Supplies, amenities, vehicles, maintenance, and overheads costs are routine expenditures and are explicitly excluded from the total additional EmONC investment budget needs. However, these costs are important as the government needs to bear in mind that EmONC facilities will continue to require regular investments for supplies, maintenance, and overheads commensurate with inflation and growth in facility-level deliveries and needs. Supplies include essential drugs, oxygen, partographs, clean and sterile gloves, and blood for transfusion. Amenities comprise water and toilet sources in maternity wards and electricity. Vehicles are medicalised ambulances.

4.4. Discussion

The goal of this Chapter was to evaluate the capacity challenges faced by EmONC facilities and to develop EmONC investment proposals that promote resources prioritisation and allocation. Strengthening the Burundian EmONC facilities is strategically sensible because records prove that these facilities manage about two-thirds of all obstetric complications amongst the 85% of deliveries currently taking place in health facilities nationally.[146,147] Moreover, increasing EmONC facility capacity and performance could attract more maternal referrals and improve survival.

To conduct this study, I actively involved Burundian policymakers and MNH stakeholders who contributed to the development of three EmONC resource benchmarks for alternative facility strengthening scenarios. However, it is noteworthy that all of these policy benchmarks, although the highest scenario proposes promising sets of resources, set relatively modest resource standards. Regarding human resources for instance, although we lack international standards for either numbers of delivery care professionals needed for maternity hubs,[249,291] the International Federation of Gynecology and Obstetrics (FIGO) suggests that BEmONC facilities with 1000 deliveries per year should ideally have three delivery professionals per shift and there should be seven of these professionals per shift in CEmONC facilities that perform 3000 deliveries annually.[249] Examining prevailing workloads in Burundian EmONC facilities indicates that none of the staffing benchmarks examined meets these recommendations but I postulate that the highest benchmark, the expert maximum proposal, proves to offer a progressive move for Burundi.

Findings pointed to widespread and severe shortages of EmONC resources and highlighted notable disparities between facility types and provinces. The extent of resource deficits together with apparent imbalance between staffing levels and prevailing workloads raises critical questions about how or whether such facilities can sustain effective routine service delivery daily. For instance, five BEmONC and two CEmONC facilities are without a midwife or a maternity-specific nurse even though they are open seven days and 24 hours. More generally, findings of this Chapter demonstrate that EmONC resources and measures of services provided are poorly aligned, with facilities facing severe understaffing often performing more deliveries and

handling more complications. The findings of this Chapter are important as they provide one assessment of the effectiveness of EmONC investments after eight years of programmatic activity and suggest that Burundi continues to face structural challenges including resource prioritisation and allocation; these aspects will be explored and addressed in the dedicated Chapters 6 and 7, respectively. In fact, despite policy efforts and strategic investments to address shortages and maldistribution of health resources,[292] many LMICs continue to face longstanding challenges to optimise resources allocation.[292-294]

Assuming that Burundi has a sufficient stock of unemployed health professionals and does not need to train additional cadres in the short run,[295,296] this country needs an estimated US$ 32.9 million to address the highest (i.e., expert maximum) benchmark resources over the next five years. If capital investments are made in the first year (e.g., in 2025/2026) together with the first round of biennial EmONC training, the government is expected to spend 45% of the total budget in that year (see Table 4.8). Averaged across the 5 years, the US$ 32.9 million additional budget approximates to an annual 5.96% increase of the total health budget. Human resources account for 37%, capital investment for 25%, and other recurrent resources comprising EmONC equipment and laboratory needs account for 38% of this additional budget. The analyses showed that EmONC training is very expensive with nearly US$ 8,131.99 expenditure needed to train one professional (see Supplemental material 12). Results exploring the impact of the routine EmONC training on provider competence are presented in Chapter 5. Alternative and potentially more efficient investments might be made to improve health worker skills and practice, for example by investing in improving staff numbers and better supervision with on-site training by (visiting) senior professionals.

In light of these findings, Burundi would likely require extensive financial support from current and potential EmONC partners such as UNFPA, WHO, UNICEF, The World Bank, JICA, USAID, and others. The results of this Chapter could help to understand which and where EmONC resources are most needed although without paying attention to prevailing workloads. If the budget that can be mobilised proves insufficient to cover all the needs immediately, there may be interim options to target investments in human and capital resources to provinces and facilities with critical

shortages and high demand for delivery care services which we highlighted throughout this Chapter but more empirical, precise policy directions will be developed in the Chapters 6 and 7.

Strengths and limitations of Chapter 4

The strengths of this study include the involvement of stakeholders, the study scale (i.e., all EmONC facilities), and the various data sources. But analyses performed in this Chapter have some limitations. First, I did not specifically address equity at this level of analysis as I was limited in examining the supply of services and not potential demand and I had no information on wealth distribution across the populations accessing care. Second, the costing approaches have many areas where uncertainty is obvious. Particularly, I recognise that resources itemisation and quantification and the cost allocation are prone to endogenous uncertainty.[297,298] For instance, despite a thorough literature review and the involvement of stakeholders, it is possible that I failed to account for all useful EmONC resources during the identification and quantification of various EmONC resources presented in Table 4.1 thus omitting other, possibly necessary resources. Finally, the methodological approach of budget forecasting failed to account for possible differences based on geographic locations of facilities as I assumed for instance that the cost of acquisition of a delivery room and other resources is the same across the country.

4.5. Conclusion

This study highlighted that despite eight years of programmatic investments, Burundian EmONC facilities continue to face enormous capacity challenges that threaten the overall performance and sustainability of maternal and neonatal service delivery. Even when assessed against benchmarks that remain sub-optimal, especially with regard to human resources, the country requires an estimated financial commitment ranging between US$ 13.6 and 32.9 million to strengthen the capacity of these EmONC facilities for the next five years. Fortunately, the Burundian MNH programme has long benefited from political determination and stakeholder resolve alongside the engagement of numerous potential donors and development partners who support the country's efforts to advance its MNH agenda. These assets present

valuable opportunities for resource mobilisation while findings from this Chapter have the potential of aiding in strategic planning and resource allocation.

Finally, findings from this Chapter provide a critical evidence, a base serving as a foundation for more detailed and continuous EmONC network capacity evaluation. Further analyses should focus on prioritising EmONC facilities to help Burundian policymakers make informed investment decisions in the event of limited resources, predict the costs and benefits of any investment proposal put forward to policy debate, and examine whether existing delivery workers have necessary competence to appropriately handle maternal and newborn complications.

In the remaining Chapters I focus on human resources to develop possible workforce investment proposals aimed at strengthening these EmONC facilities. First, I examine in Chapter 5 the competence of delivery care providers in performing care linked to EmONC with an aim to inform the redesign or tailoring the routine, costly EmONC training to specific providers. In the sixth Chapter, I develop and implement a prioritisation framework in the effort to identify a set of EmONC facilities worthy of a priority investment if Burundi cannot raise the US$ 32.9 million in the short-run to fully address identified capacity gaps assessed against the highest and most promising resource benchmark. Finally, the seventh Chapter aims to review the workforce gap estimation using the WISN method. Backing on stakeholder input, I develop in this seventh Chapter four possible EmONC workforce investment scenarios with costs and benefits estimates to inform decision-making discussions.

CHAPTER 5. EXAMINING PROVIDER COMPETENCE

This Chapter contains some of the content of a manuscript under review in BMC Medical Research Methodology (Ref: Submission ID 2fd6634b-76e2-42d2-b16c-7925360bcedd; The application of Item Response Theory to revolutionise analysis of clinical competence of health workers: a cross-sectional vignette-based EmONC competence test of Burundian delivery care professionals). This manuscript is provided as Appendix 4.

I begin this Chapter by highlighting key findings in Box 5.1, demonstrating policy implications on these results. Following this highlight, I introduce the analytical methods employed to examine EmONC competence, setting the tone for a deeper understanding of the approach. In this analysis, I utilised a method for which I provide a solid rationale that may be less familiar compared to traditional approaches commonly used in analysing competence. Indeed, unlike the most common frequentist statistical methods such as summated scores, Principal Component Analysis (PCA), Analysis of Variance (ANOVA), amongst others, the method used in this chapter – the Item Response Theory (IRT) – enables one to predict a latent trait (i.e., competence) using real test scores by assuming an infinite repeat of the test administration. It also discriminates examinees based on the difficulty level of various test items and further permits one to test and validate a new (or update an existing) instrument aimed at examining competence better than frequentist methods.

In this Chapter, I will employ the term "latent" competence to refer to an underlying attribute or ability that cannot be directly observed in isolation. In IRT measurement framework, this latent trait, denoted as theta (θ), represents an individual's true level of competence on a given domain (e.g., performing a breech delivery) inferred from observed data (i.e., responses on tasks aimed to test performance) through the pattern of correct or incorrect answers. Laten traits are abstract and multidimensional, cannot be measured directly, and explain why different individuals respond differently to items of differing difficulty.[299,300]

Box 5.1 Key findings from Chapter 5

Existing knowledge

- Beyond sufficient numbers, EmONC-competent delivery care providers are crucial for delivering quality care and saving lives. However, competence is a latent trait difficult to comprehend with frequentist statistics.
- Statistical analyses of competence have commonly relied on classical test theories such as summative scores and principal component and factor analyses, but these frequentist methods do not accommodate important hypotheses underpinning this form of assessment (e.g., competence is a latent outcome, different competence test sections have varying levels of difficulty, among other analytical considerations which I detail in this Chapter).

Methods

- Based on EmONC clinical guidelines, the Burundian EmONC training curriculum, and contributions from 23 MNH experts, I designed five EmONC clinical vignettes representing the most common maternal and newborn complications and examined 311 delivery care professionals across all 112 Burundian EmONC facilities. I compared summated scores and one-way ANOVA results with IRT findings, documenting analytical merits of IRT features particularly the item and total characteristic curves used to apprehend the test difficulty and predict expected scores assuming an infinite repeat of test administration. Furthermore, I estimated the latent competence using empirical Bayes means and tested instrument validity using the test information function (TIF).

Key findings

- Summated statistics and the IRT model produced comparable overall results but the latter offered more nuanced insights. The Item Characteristic Curve (ICC) analysis identified the most challenging test components. ANOVA findings, those from the Test Characteristic Curve (TCC) analysis and empirical Bayes means estimates collectively demonstrated that higher qualifications positively impact EmONC competence. Based on ANOVA results, nurses scored 44% on the EmONC competence test, midwives 56%, and doctors 70% while the TCC indicated that random samples of nurses, midwives, and doctors in Burundian EmONC facilities would achieve 45%, 57%, and 62% respectively. Correspondingly, the empirical Bayes means confirmed that doctors have EmONC competence $\theta=1.13$ (SD=0.88), midwives $\theta=0.40$ (SD=0.84), and nurses

θ=–0.12 (SD=0.95) on θ±4 scale. Finally, the test instrument provided precise estimates for professionals with $-0.5 < \theta < 0.5$ and was therefore suited for midwives and nurses.

Policy and practice implications

- Although ANOVA and IRT findings corroborated one another, comparison of these analytical methods demonstrated that IRT allows us to discriminate participants based on question difficulty levels and to predict underlying competence, analysis frequentist statistical methods cannot perform. Therefore, besides assessing EmONC competence of delivery care providers, the IRT method was used to provide more comprehensive and informative analyses, which also help in testing and validating the competence assessment instrument. This contribution to research methodologies is particularly useful for researchers who are interested in designing competence evaluation studies and developing or updating tools to examine competence tailoring them to particular categories of health professionals.

5.1. Background

Competent delivery care professionals in Burundian EmONC facilities are crucial to saving lives. It is estimated that 340 Burundian women and 2,300 newborns die for each 100,000 deliveries, mainly from obstetric and newborn complications that could be averted if quality obstetric care is delivered.[34,279,301] The SDGs agenda highlights the need for sufficient skilled delivery care professionals to deliver on the maternal and neonatal agenda,[148,149] and mounting evidence underscores that quality care is only possible with competent health workers capable to correctly perform salient clinical tasks.[150,151] Unfortunately, research has found that a significant proportion of qualified health workers specifically in LMICs have insufficient skills to offer correct care for most maternal and newborn complications.[151-154] For countries like Burundi which aspires to achieve about 60% and 50% reductions in maternal and newborn mortality rates respectively by 2030, understanding health worker competence in designated EmONC maternities is helpful to inform practice, actions and policy change.

There are multiple approaches to assessing competence, a latent trait that is inherently challenging to measure. Competence is influenced by the individual knowledge and

skills and further relies on an enabling environment; therefore direct observation of clinical task performance remains its ideal assessment method.[302] However, operationalising such observations in clinical practice and on a sufficient and representative sample can be extremely difficult in practice. Owing to this practical challenge, various alternative methods to evaluate competence in clinical medicine have emerged, the most common being vignettes, written tests, computer-delivered tests, performance records, physical models, and task samples.[150,303,304] Each of these methods has its strengths and limitations, but they collectively contribute to a more comprehensive understanding of a clinician's competence. Of them, vignettes are regarded as a particularly effective option; they are generally less tedious and more cost-effective especially in LMICs where routine chart documentation may be incomplete or altogether absent.[156] Clinical vignettes allow for the assessment of clinical decision-making and problem-solving skills in a controlled manner, providing valuable insights into a clinician's ability to apply knowledge in hypothetical scenarios and this is particularly helpful in contexts where direct observations are impractical.

Statistical analyses of competence based on vignettes have typically relied on classical test theories such as summative scores and principal component and factor analyses,[152,305-308] but these frequentist methods do not accommodate important hypotheses underpinning this form of assessment. First, competence test components generally differ substantially in their degree of difficulty and are particularly so with obstetric vignettes in that some routine clinical practices are commonly intuitive (e.g., measuring blood pressure) while other tasks require advanced clinical expertise (e.g., instrumental childbirth and neonatal resuscitation).[309,310] Second, assuming that they don't recall previous answers, we would expect examinees to fare differently if the competence test was administered repeatedly over a relatively short period of time, and these scores would cluster themselves around some average value corresponding to an individual's 'true' score.[309] Therefore, simpler statistical analyses particularly those using equal weighting fail to discriminate between easy and difficult test components. Further, these methods simply rely on summary scores to estimate competence ignoring that the latter is a latent feature different from obtained scores.

IRT, a psychometric competence analysis technique which emanates from the sectors of education and psychology,[311] offers a means to address these issues[308,312-314] while

allowing a simultaneous computation of the predicted true scores along with the latent competence.[302,315] Nonetheless, despite its documented advantages over summary statistics, this form of analysis has rarely been applied to examining competence of health workers and those that used it did not demonstrate methodologically how it can be done using applied statistical packages such as the statistical software for data science (STATA).[302,316,317] This chapter demonstrates the application and rewards of IRT in examining competence of health workers using delivery care providers in Burundian EmONC facilities. Specifically, I compare summated and one-way ANOVA scores with IRT findings and use IRT attributes to isolate the most difficult questions and test components, detect how easy and difficult test sections affect performance of different delivery care professionals, and predict the expected scores and the underlying competence assuming an infinite number of test repeats. Finally, I demonstrate how IRT enables us to design new or update existing competence test instruments tailoring them to particular categories of health professionals.

5.2. Methods

5.2.1. Study design and setting

I conducted a cross-sectional study to examine EmONC competence among nurses, midwives, and medical doctors working in maternity across all EmONC facilities in Burundi (n=112; 53 CEmONC and 59 BEmONC facilities). In 2021, there were 319 delivery care professionals posted to EmONC maternities. They comprised 51 doctors across 31/53 CEmONC facilities and 3/59 BEmONC facilities, 103 midwives across 49/53 CEmONC and 5/59 BEmONC facilities, and 165 EmONC nurses in 34/53 CEmONC and 51/59 BEmONC facilities. In the same year, the CEmONC facilities performed between 331 and 3737 (median 1622) deliveries and handled from 149 to 2385 (median 876) maternal complications and 29 to 816 (median 247) newborn complications and the BEmONC facilities performed 493 to 2431 (median 1365) deliveries and managed from 77 to 1748 (median 805) maternal complications and 15 to 670 (median 215) newborn complications.[318]

5.2.2. Study participants and data collection

The Burundian policy indicates that all qualified delivery care professionals namely nurses, midwives, and doctors must receive the standard EmONC training to upgrade their clinical skillset linked to the management of the most maternal and newborn complications except emergency surgery (i.e., hysterectomy and caesarean section) which requires the competence of medical doctors. It is therefore expected that doctors, midwives, and nurses in these EmONC maternities are familiar with care for routine childbirth and for various emergency complications excluding surgery.[318] Therefore, the EmONC competence test excluded obstetric surgery which discriminates midwives and nurses but instead concerned the remaining EmONC spectrum targeting all delivery care providers irrespective of their qualifications. The EmONC competence test was conducted during facility visits and was administered by 54 examiners grouped into 18 teams; one team per province of Burundi as detailed in Section 3.6. Those administering the test were medical doctors who received standard training and who demonstrated consistent comprehension of the administration of questions during pretesting. Each team of examiners was supervised by an experienced MNH expert and together visited all EmONC facilities in their assigned province over a period of five days in July 2022; examining between two to four delivery care professionals in each facility.

5.2.3. Sample size estimation

Drawing on evidence from other African and Asian low-income contexts[151,153,154,319] and using the cross-sectional sample size estimation method for prevalence $p = 0.25$ (anticipating that one in four Burundian delivery care professionals would pass the EmONC competence exam), with $z = 1.96$ for a 95% confidence level and a margin of error ($\varepsilon = 0.05$), I estimated that a minimum sample of 289 delivery care professionals would be required for the study. Based on the average workforce capacity of Burundian facilities, I expected 118 delivery care professionals in BEmONC facilities and 212 professionals in CEmONC facilities; thus my sample estimate represented approximately 88% (289/330) of the expected universe of possible delivery care professionals in these designated facilities. This sample did not include obstetricians,

paediatricians, and neonatologists who only exist in tertiary and academic hospitals in Bujumbura and do not provide routine maternity and neonatal care. The health facility assessment (see Supplemental material 7) identified that a total of 319 delivery care professionals are assigned to the maternity and neonatology units across all the 112 EmONC facilities. Therefore, my estimate sample of 289 participants represented approximately 91% of the total study population, which enhances the robustness and representativeness of the study.

5.2.4. EmONC clinical vignettes construction

I designed five EmONC clinical vignettes representing the most common maternal and newborn complications in Burundi (Table 5.1) based on the guide for health workers on the management of complications in pregnancy and childbirth jointly developed by WHO, UNFPA, and UNICEF.[155] This guide was the basis of the nationally deployed Burundian EmONC training curriculum and the EmONC provider skillset requirements. These vignettes are a battery of questions for hypothetical cases and were designed in collaboration with MNH clinicians and experts namely researchers, implementers, and professional associations. Examinees were provided with each hypothetical clinical case individually and asked without prompting to proceed with care as they would under actual circumstances. Using vignette 2 as an illustration, the examiner informed an examinee that a pregnant woman presents with symptoms of severe malaria and asked the immediate actions to undertake and the danger signs to monitor. In this case, the latter actions and danger signs represent my *response items* and were fully explained during EmONC training and are further commonly supplemented in maternity wards as clinical guidelines. All vignettes used a similar approach and the examiner recorded 1 if examinee i correctly provided *response item* j, and 0 if the response was wrong or not given.

5.2.5. Data analysis

5.2.5.1. Descriptive statistics

I began data analysis with simple explorations, determining proportions of correct responses on each item and identifying items and vignettes that are most challenging.

Next, I generated the total raw scores out of 115 (the maximum possible score with equal item weighting) for each participant and summarised them by category of delivery care professionals and further by facility type (i.e., BEmONC versus CEmONC) focusing on midwives and nurses, as doctors are by design only posted to CEmONC facilities. At this level of analysis, I explored the inter-item correlations within and across vignettes and examined the test reliability using Cronbach's alpha. Group summaries of raw scores were compared using one-way ANOVA to examine the mean score differences between nurses, midwives, and doctors for each vignette and on the whole set of vignettes. Furthermore, I aggregated and summarised crude scores by health district and by province, principally to explore whether specific provinces had lower mean scores to inform further EmONC training needs using a forest plot to illustrate the findings.

Vignette cases and corresponding sub-questions	Response items (n)
Vignette 1. Labour monitoring (n=3)	**20 response items**
What are the key elements to regularly monitor during childbirth?	10 response items
What are the indications and key components of the active management of the third stage of labour?	5 response items
What are the safety measures to undertake for preventing septic childbirth?	5 response items
Vignette 2. Management of malaria during pregnancy (n=2)	**13 response items**
What are the immediate actions to take when a pregnant woman presents severe malaria symptoms?	5 response items
What are the danger signs of severe malaria during pregnancy?	8 response items
Vignette 3. Management of postpartum haemorrhage (n=5)	**41 response items**
What are the danger signs to monitor in case of abundant maternal bleeding?	7 response items
What are the important and systematic actions to do in case of abundant maternal bleeding?	9 response items
What are the key and systematic actions to do in case of a retained placenta?	10 response items
What are the signs to monitor when a mother develops malaise within 48 hours after delivery?	6 response items
What are the key actions to undertake following an incomplete or an unsafe abortion?	9 response items
Vignette 4. Management of severe preeclampsia and eclampsia (n=6)	**24 response items**
What do you suspect when a mother presents severe headaches and abdominal pain?	4 response items
What are the positive signs to check to confirm suspected severe preeclampsia?	5 response items
What are the essential monitoring elements in case of severe preeclampsia?	6 response items
What are the important and systematic actions to do after confirmation of severe preeclampsia?	4 response items
What are the key signs to assess before a repeat administration of magnesium sulfate (MgSO4)?	3 response items
What are the key actions to do in case of a cardiopulmonary arrest after the administration of MgSO4?	2 response items
Vignette 5. Immediate care for the newborn (n=3)	**17 response items**
What are the systematic elements of newborn care immediately after birth?	8 response items
What are the essential and systematic steps of birth asphyxia treatment?	6 response items
What is the systematic approach of PMTCT?	3 response items
Total number of questions (n=19)	**115 response items**

Table 5.1 shows the number of questions and response items in each clinical vignette. In total, the whole EmONC competence test comprised five vignettes and 19 questions with a total 115 possible response items. The third vignette concerned the management of postpartum haemorrhage and accounted for 35% of response items (n=41).

5.2.5.2. Item Response Theory analytical concepts

Each examinee responding to a test item possesses some level of underlying ability (i.e., latent prior competence) that determines the probability of a correct answer to that particular item (see Equation 5.1).[320] Conceptually, IRT updates the latter prior competence with actual test scores to predict the posterior competence and further uses the empirical Bayes means estimates and the standard errors to examine the validity of the overall test instrument.[320] This method enables us to distinguish the levels of test difficulty for each item and to predict true scores that an examinee with a given level of prior competence would achieve if the test were to be administered an infinite number of times.[321] Thus, IRT is particularly helpful to determine whether the test instrument is powerful for examining competence across all test takers or whether it is more robust to capture this competence in particular categories of these examinees (e.g., such as nurses).[322] For brevity, the terms ability and competence are employed interchangeably, true score denotes the predicted success rate assuming an infinite repeat of test administration, and true competence designates posterior competence which, together with the item difficulty, are continuous metrics that can range from $-\infty$ to $+\infty$.

$$TS_i = \sum_{j=1}^{J} P_j(\theta_i) \qquad \text{Equation 5.1}$$

where

TS_i	is the true score for examinees with ability level θ_i
j	corresponds to an item; J is total number of items
$P_j(\theta_i)$	is the probability of success to item j which depends on the ability level θ_i.

5.2.5.3. Test difficulty and predicted test scores

Response items were dichotomous taking value 1 if respondent i correctly gives *item response* j, and 0 otherwise; and the total raw score for respondent i ranged between 0 and 115. I denoted b_j to represent the difficulty of *response item* j and θ to denote the examinee's underlying EmONC competence. Therefore, each response to an item represented an encounter between examinee of ability θ and an item of difficulty b_j such that professionals with higher θ than b_j have the likelihood of faring 1.[312,323] This relationship between θ and b_j further implies that if $\theta < b_j$, the probability of

success to *item response j* tends towards 0 and becomes 0.5 if these two parameters are equal (see Equation 5.2). I used a one-parameter logistic model (1PL) and the item characteristic curves (ICC) to determine item difficulties, describing the probability that respondent i succeeds on each response item. The ICC uses three parameters of the logistic functional form of the IRT model; the *guessing* parameter which represents the probability that a provider with the lowest possible competence will correctly respond to item j, the *discrimination* parameter which corresponds to the maximum slope of the curve, and the *difficulty* parameter corresponding to the competence level θ at which the probability of responding correctly to item j equals 0.5. Because I assumed a zero mean for θ, response item j was believed to be relatively easy if its difficulty estimate was negative and relatively hard if its difficulty estimate was positive. For comparison purposes, I reported each item difficulty level along with the proportion of examinees who succeeded on it.

$$\Pr(Y_{ij} = 1 \mid b_j, \theta_i) = \frac{\exp(\theta_i - b_j)}{1 + \exp(\theta_i - b_j)} \qquad \text{Equation 5.2}$$

where

Y_{ij}	represents the (yet to be observed) outcome for item j from person i
b_j	corresponds to item j difficulty level
θ_i	is the ability level of provider i
$(\theta_i - b_i)$	ranges from - ∞ to + ∞

Next, I predicted the expected true score or success rate that examinee i with competence θ_i would achieve if the EmONC test were taken repeatedly. To express this more clearly, given that θ_i is a latent trait being examined using the EmONC competence test, I transformed the latter θ_i into the proportion 'true score', corresponding to the proportion of response items an examinee with θ_i is expected to answer correctly where expectation is the average score over repeated administrations of the same competence test. The total characteristic curve (TCC) function of the IRT model plots expected scores on the competence test along the latent trait (θ) continuum. As my EmONC competence test contained 115 binary response items each coded 0 or 1, an examinee i would score between 0 and 115. I used the 95% critical threshold from a standard normal distribution ($z = \pm 1.96$) to predict the expected average (and the minimum and maximum) scores any random sample of nurses, midwives, and medical doctors would achieve on this EmONC competence test.

Finally, I updated the posterior latent competence by predicting θ for each test taker using the empirical Bayes means estimates which combine prior information about the latent competence θ with the likelihood function (actual test scores) to obtain the conditional posterior θ distribution. The posterior θ represents the true competence and generally ranges between –4 and 4 with participants with θ in the vicinity of zero being believed to be averagely competent. I examined the distribution of true competence by category of delivery care professionals and by facility type and further investigated the effects of qualification, previous EmONC training, delivery experience, type of employment, sex, and age of professionals on competence using linear regression. This regression included quadratic terms for age and previous deliveries to examine possible non-linear relationships with competence. Specifically, I ran complete and then saturated linear regressions each containing an additional dichotomous predictor variable coding for providers with and without EmONC training by type of professionals to explore the effects of qualification and EmONC training on true competence. Diagnosis of the linear regression models detected heteroskedasticity so I obtained robust estimates by performing 10,000 bootstrap resamples to improve the accuracy of the standard errors.[324]

5.2.5.4. EmONC competence test validity assessment

Although my EmONC competence test drew on clinical EmONC guidelines[155] and the standard EmONC training curriculum and further benefited from contributions of MNH experts, my instrument (i.e., the clinical vignettes) had never been tested and validated before. I was therefore uncertain whether this instrument is accurate in capturing EmONC competence among Burundian doctors, midwives, and nurses at the same time even though these professionals receive the same EmONC training apart from emergency obstetric surgery which concerns medical doctors and was not part of the competence exam. Test validity was diagnosed using the test information function (TIF) of the IRT model; determining the competence range where this instrument provides more information by minimising standard errors. This maximum precision range therefore reveals the types of participants whom the test is particularly suitable for. Indeed, moving away from that precision interval in either direction increases the

standard error and the instrument becomes inaccurate; providing less information about θ.

5.3. Results

5.3.1. Descriptive statistics and raw data analysis results

I examined a convenient sample of 311 professionals comprising 257 nurses, 40 midwives, and 14 medical doctors who were on duty during our visits. This sample represents 97.49% of the total 319 delivery care professionals who exist across all the 112 EmONC facilities. About half of the 311 examinees came from either type of facility (159/311, 51% in BEmONC facilities and 152/311, 49% in CEmONC facilities), but BEmONC facilities had more nurses (152/257, 59%) while CEmONC facilities had more midwives (34/40, 85%) and the vast majority of doctors (13/14, 93%). Higher qualified professionals were predominantly male with 152/257 (60%) female nurses against 26/40 (65%) male midwives and 13/14 (93%) male doctors. On the whole, one in three examined professionals was below 35 years and 95% of all participants were below 50. I found that 96% (300/311) of professionals had more than 2 years of maternity experience although above half (161/311, 52%) had never received EmONC training before.

Crude test results in Tables 5.2 show that few delivery care professionals in Burundian EmONC facilities have the needed competence across all clinical vignettes. For instance, the proportions of correct answers in each vignette prove that test takers performed better in vignettes on labour monitoring (64.3%) and routine neonatal care (58.6%) and fared badly on those regarding the management of severe preeclampsia and eclampsia (35.6%), fever and malaria (36.5%), and postpartum haemorrhage (45.4%). With respect to specific clinical tasks, only 17% of examinees demonstrated the necessary knowledge that could enable them to effectively manoeuvre the perineum during the active management of the third stage of labour and to identify standard danger signs of severe malaria during pregnancy. Further, findings in Tables 5.2 indicate that not one of the examined professionals knew the respiratory rate criterion that indicates whether it is safe to repeat doses of magnesium sulphate (MgSO4) during the management of hypertensive disorders and only one in twelve would regularly

assess clotting signs to rule out coagulopathy during MgSO4 treatment. In Tables 5.2A–E, I provide the proportion of professionals who correctly answered each clinical aspect of care alongside the corresponding difficulty level of that care aspect estimated through the IRT methodology. The purpose is to illustrate how the summated, descriptive statistics align with the predicted difficultly levels. For instance, Table 5.2B shows that the components with a negative difficulty level, indicating easier components, were commonly answered correctly by high proportions of professionals. In contrast, fewer professionals correctly responded to the more challenging aspects; those with higher difficulty levels. These preliminary explorations are therefore valuable because they offer an in-depth view of the EmONC competence test, highlighting sections that were most accessible and which ones posed the greatest challenges for participants. This detailed understanding could inform targeted actions and improvements in designing EmONC training and assessment tools.

Question	Item number and correct practice	Professionals with correct answers (n, %)	Item difficulty level (b_j)
What are the key elements to monitor regularly during childbirth?	1. Fetal heart rate	304 (97.75)	—3.07
	2. Cervical dilatation	293 (94.21)	—2.37
	3. Mother's blood pressure	266 (85.53)	—1.59
	4. Mother's temperature	239 (76.85)	—1.11
	5. Uterine contractions	219 (70.42)	—0.82
	6. Mother's pulse	210 (67.52)	—0.71
	7. Head descent	188 (60.45)	—0.42
	8. Mother's breathing rate	186 (59.81)	—0.39
	9. Fetal head position	117 (37.62)	0.44
	10. Urine protein	179 (57.56)	1.39
What are the components of the active management of the third stage of labour?	11. Oxytocin injection	287 (92.28)	—1.79
	12. Controlled cord traction	162 (52.09)	—0.63
	13. Uterine massage after delivery of the placenta	155 (49.84)	—0.63
	14. Routine examination of the vagina and perineum	55 (17.68)	—0.39
	15. Examination of the placenta and membranes	304 (97.75)	0.31
What are the safety measures to undertake to prevent septic childbirth?	16. Wear sterile gloves on both hands	179 (57.56)	—2.14
	17. Put on a clean plastic apron, boots and glasses	275 (88.42)	—1.32
	18. Wash hands with antiseptic soap, dry with a sterile cloth	205 (65.92)	—0.31
	19. Clean the perineum with a compress soaked in antiseptic solution, wiping from front to back	122 (39.23)	—0.10
	20. Place three sterile drapes, one under the woman's buttocks, one over her abdomen, and the other one reserved to receive the newborn	252 (81.03)	—0.02

Table 5.2A Difficulty levels of clinical vignette 1: Labour monitoring and infection prevention during childbirth

Question	Response items	Professionals with correct answers (n, %)	Item difficulty level (b_j)
What are the actions to do when a pregnant woman has severe malaria symptoms?	21. Quinine and dextrose IV	252 (81.03)	—1.76
	22. Proceed immediately with admission	215 (69.13)	—0.99
	23. Start the vital signs chart	179 (57.56)	—0.38
	24. Check haemoglobin	133 (42.77)	0.35
	25. Blood slide for MPS	112 (36.01)	0.70
What are the danger signs of severe malaria during pregnancy?	26. Jaundice (Yellowish eyes)	134 (43.09)	0.33
	27. Dizziness	119 (38.26)	0.58
	28. Fever (above 38°C)	93 (29.90)	1.04
	29. Pallor	74 (23.79)	1.42
	30. Condition of the foetus	68 (21.86)	1.55
	31. Joint pain	64 (20.58)	1.64
	32. Confusion/Coma	55 (17.68)	1.87
	33. Dehydration	55 (17.68)	1.87

Table 5.2B Difficulty levels of clinical vignette 2: Management of fever and malaria during pregnancy

Question	Response items	Professionals with correct answers (n, %)	Item difficulty level (b_j)
What are the danger signs to monitor in case of abundant maternal bleeding?	34. Signs of shock (dizziness, low BP)	220 (70.74)	—0.86
	35. Genital tract injuries	218 (70.10)	—0.84
	36. Retained products/placenta	213 (68.49)	—0.77
	37. Signs of anaemia	193 (62.06)	—0.52
	38. Uncontracted uterus	165 (53.05)	—0.18
	39. Amount of external bleeding	141 (45.34)	0.11
	40. Check if bladder is full	48 (15.43)	1.59
What are the important and systematic actions to do in case of abundant maternal bleeding?	41. Give ergometrine IM or IV (Oxytocin)	225 (72.35)	—0.93
	42. Examine the woman for lacerations	217 (69.77)	—0.82
	43. Manual removal of retained products	202 (64.95)	—0.63
	44. Start IV fluids	199 (63.99)	—0.59
	45. Massage the fundus	130 (41.80)	0.25
	46. Take blood for haemoglobin and crossmatching	129 (41.48)	0.26
	47. Empty the woman's bladder	66 (21.22)	1.20
	48. Raise foot of bed	66 (21.22)	1.20
	49. Inform a medical specialist	20 (6.43)	2.53
What are the key and systematic actions to do in case of a retained placenta?	50. Give IV fluids	239 (76.85)	—1.14
	51. Apply manual removal of the placenta	200 (64.31)	—0.60
	52. Repeat oxytocics	114 (36.66)	0.46
	53. Test blood for group and cross match	100 (32.15)	0.65
	54. Check uterus is well contracted	93 (29.90)	0.75
	55. Monitor vital signs for shock & act	84 (27.01)	0.89
	56. Empty urinary bladder	60 (19.29)	1.32
	57. Apply controlled cord traction	49 (15.76)	1.56
	58. Inform a medical specialist	39 (12.54)	1.83
	59. Prepare for theatre	35 (11.25)	1.95
What are the signs to monitor when a mother develops malaise within 24 hours after delivery?	60. Septic shock (unrecordable blood pressure)	249 (80.06)	—1.31
	61. Tender abdomen	182 (58.52)	—0.38
	62. High pulse	179 (57.56)	—0.35
	63. Sensitive underinvoluted uterus	159 (51.13)	—0.11
	64. Foul smelling lochia	136 (43.73)	0.17
	65. High fever	98 (31.51)	0.68
What are the key actions to undertake	66. Do manual vacuum aspirations (MVA)	190 (61.09)	—0.48
	67. Start on antibiotics	187 (60.13)	—0.44

following an incomplete or an unsafe abortion?	68. Assess the vital signs	186 (59.81)	—0.43
	69. Assess the bleeding	155 (49.84)	—0.06
	70. Do vaginal examination	153 (49.20)	—0.03
	71. Do conventional evacuation (D&C)	105 (33.76)	0.58
	72. Start on IV fluids	85 (27.33)	0.87
	73. Provide counselling	64 (20.58)	1.24
	74. Inform a medical specialist	19 (6.11)	2.58

Table 5.2C Difficulty levels of clinical vignette 3: Management of postpartum haemorrhage

Question	Response items	Professionals with correct answers (n, %)	Item difficulty level (b_j)
What to do when a mother presents severe headaches and abdominal pain?	75. Take vital signs (especially temperature and BP)	272 (87.46)	—1.59
	76. Check the term of pregnancy	163 (52.41)	—0.12
	77. Get details about the abdominal pain (epigastric)	106 (34.08)	0.52
	78. Confirm any visual problems (blurred vision)	76 (24.44)	0.93
What are the positive signs to check to confirm suspected severe preeclampsia?	79. High level of BP (diastolic > 100mmhg)	256 (82.32)	—1.29
	80. Severe headache	213 (68.49)	—0.69
	81. Proteinuria (3+)	192 (61.74)	—0.44
	82. Visual disturbance	132 (42.44)	0.22
	83. Epigastric pain	116 (37.30)	0.40
What do you monitor during severe preeclampsia treatment?	84. Monitor vital signs, reflexes and FHR hourly	209 (67.20)	—0.64
	85. Test proteinuria	90 (28.94)	0.73
	86. Maintain a strict fluids balance chart and monitor the amount of fluids intake to avoid fluid overload	87 (27.97)	0.76
	87. Monitor for possible pulmonary oedema	60 (19.29)	1.20
	88. Catheterize the bladder to monitor urine output	59 (18.97)	1.21
	89. Assess clotting to rule out coagulopathy	25 (8.04)	2.04
Severe preeclampsia is confirmed, what actions to be undertaken?	90. Continue treatment with Mgso4 for 24 hours after delivery or convulsion (whichever is late)	106 (34.08)	0.53
	91. Give 20% magnesium sulfate solution 4g IV, over 5 minutes	87 (27.97)	0.78
	92. Follow promptly with 50% magnesium sulfate solution 5g, IM in each buttocks with 2% lignocaine 1ml in the same syringe	66 (21.22)	1.09
	93. After every 4 hours, continue the maintenance dose of 50% magnesium sulfate solution 5g; with 2% lignocaine 1ml in the same syringe, in IM into alternate buttocks	50 (16.08)	1.39
Precautions to observe before administering the maintenance dose of MgSO4	94. Respiratory rate should be at least 16 cycles per minute	0 (00)	n.a.
	95. Urinary output is at least 30ml/hour over 4 hours	66 (21.22)	1.09
	96. Patellar reflexes are present	46 (14.79)	1.47
Actions for cardiac or pulmonary arrest following MgSO4 administration	97. Assisted ventilation	99 (31.83)	0.62
	98. Give Calcium gluconate 1g (or 10ml of 10% solution) IV slowly until respiration begins to antagonise the effect of MgSO4	136 (43.73)	0.17

Table 5.2D Difficulty levels of clinical vignette 4: Management of severe preeclampsia and eclampsia

Question	Response items	Professionals with correct answers (n, %)	Item difficulty level (b_j)
What are the systematic elements of newborn care immediately after birth?	99. Cord care (sterile cut 4–6 cm/umbilicus)	291 (93.57)	—2.64
	100. After birth of head, wipe face, nose, mouth	241 (77.49)	—1.29
	101. Assess/examine newborn within one hour	213 (68.49)	—0.83
	102. Ensure baby is breathing	200 (64.31)	—0.64
	103. Eye prophylaxis	191 (61.41)	—0.51
	104. Breastfeeding initiated within one hour	161 (51.77)	—0.09
	105. Thermal protection	132 (42.44)	0.30
	106. Baby weighed	115 (36.98)	0.54
What are the essential and systematic steps of birth asphyxia treatment?	107. Clear the airways of blood and mucus	244 (78.46)	—1.35
	108. Assist breathing with ambu bag	239 (76.85)	—1.26
	109. Provide suction if there is meconium	210 (67.52)	—0.78
	110. Dry and wrap baby in a warm clean cloth	169 (54.34)	—0.20
	111. Do cardiac massage	160 (51.45)	—0.08
	112. Place under radiant heat warmer	122 (39.23)	0.44
What is the systematic PMTCT protocol?	113. Provide NVP to infant	278 (89.39)	—2.15
	114. Offer testing for those with unknown serostatus	144 (46.30)	0.14
	115. Provide NVP in early labour for HIV+ woman	68 (21.86)	1.32

Table 5.2E Difficulty levels of clinical vignette 5: Immediate care for the newborn

Results of the ANOVA test are summarised in Table 5.3. Response items showed positive correlations both within and across clinical vignettes with an overall Cronbach's alpha coefficient of 0.945, indicating excellent internal consistency and reliability of the assessment. Table 5.3 further illustrates that the overall percent mean raw score increases with higher qualification with nurses achieving 44.0% on average, midwives 55.7%, and medical doctors 69.9%.

In general, medical doctors outperformed midwives and nurses, particularly in managing severe obstetric complications such as hypertensive complications and postpartum haemorrhage. Conversely, nurses and midwives demonstrated slightly better or comparable competence to doctors in the management of routine care tasks such as the prevention of mother-to-child transmission of HIV. This finding suggests that while higher qualification is associated with better overall performance, routine care skills are well maintained across professional groups.

On the whole, I found that all professionals have good clinical competence in labour monitoring with the mean scores ranging from 61.6% among nurses to 84.3% among medical doctors and in infection control during childbirth, with scores ranging from

59.2% among nurses to 82.9% among doctors. The province-level mean competence scores are depicted in Figure 5.1 and suggests that some provinces may have less competent staff although observed variation underscores the broader need for targeted capacity building at national level to enhance EmONC competence across regions.[318]

EmONC clinical skills questions	Items description			Percent mean scores (SD)				Group difference	
	Number and sign	Inter-item correlation	Cronbach's alpha	Overall (n=311)	Nurses (n=257)	Midwives (n=40)	Doctors (n=14)	*F* statistic	p-value
Labour monitoring (n=2)	**15, *p****	**0.59**	**0.7384**	**65.1 (25.5)**	**61.6 (25.7)**	**81.0 (14.2)**	**84.3 (22.3)**	**15.5**	**0.0000**
What are the key elements to monitor during childbirth?	10, *p**	0.22	0.7384	66.8 (22.9)	63.9 (23.2)	78.5 (14.4)	85.7 (17.4)	12.9	0.0000
What are the indications and key components of the active management of third stage of labour?	5, *p**	0.45	0.8032	63.40(34.0)	59.2 (34.5)	83.5 (20.2)	82.9 (30.2)	11.9	0.0000
Infection prevention during childbirth (n=1)	**5, *p****	**0.13**	**0.4235**	**63.4 (34.1)**	**59.2 (34.5)**	**83.5 (20.2)**	**82.9 (30.2)**	**5.9**	**0.0032**
What are the safety measures to undertake for preventing septic childbirth?	5, *p**	0.13	0.4235	63.4 (34.1)	59.2 (34.5)	83.5 (20.2)	82.9 (30.2)	5.9	0.0032
Management of malaria during pregnancy (n=2)	**13, *p****	**0.13**	**0.2299**	**36.5 (20.8)**	**35.7 (20.3)**	**34.6 (18.5)**	**59.4 (23.6)**	**9.4**	**0.0001**
What are the immediate actions when a pregnant women present severe malaria symptoms?	5, *p**	0.35	0.7249	28.3 (30.3)	28.1 (29.4)	24.5 (31.5)	42.9 (39.1)	2.0	0.1435
What are the danger signs of severe malaria during pregnancy?	8, *p**	0.21	0.6759	44.7 (24.9)	30.4 (24.2)	44.7 (22.4)	75.9 (25.7)	12.4	0.0000
Management of postpartum haemorrhage (n=5)	**41, *p****	**0.69**	**0.9182**	**45.4 (21.9)**	**42.8 (21.1)**	**53.7 (19.9)**	**70.3 (20.0)**	**15.1**	**0.0000**
What are the danger signs to monitor in case of abundant maternal bleeding?	7, *p**	0.18	0.6108	55.0 (25.3)	52.2 (24.8)	63.9 (22.4)	81.6 (19.8)	12.8	0.0000
What are the important and systematic actions to do in case of abundant maternal bleeding?	9, *p**	0.20	0.6899	44.8 (23.4)	42.0 (22.5)	54.2 (22.9)	69.0 (21.9)	13.6	0.0000
What are the key and systematic actions to do in case of a retained placenta?	10, *p**	0.28	0.7947	32.6 (24.8)	30.1 (23.6)	41.3 (25.40	52.8 (31.0)	8.8	0.0002
What are the signs to monitor when a mother develops malaise within 48 hours after delivery?	6, *p**	0.20	0.6062	53.8 (27.6)	51.2 (27.2)	60.0 (25.8)	82.1 (23.1)	10.1	0.0001
What are the key actions to undertake following an incomplete or an unsafe abortion?	9, *p**	0.22	0.7132	40.9 (25.0)	38.2 (24.4)	49.2 (23.3)	65.9 (23.2)	11.4	0.0000
Management of preeclampsia & eclampsia (n=6)	**24, *p****	**0.53**	**0.8706**	**35.6 (24.1)**	**31.7 (22.8)**	**50.2 (19.9)**	**64.5 (23.7)**	**23.8**	**0.0000**
What do you suspect when a mother presents severe headaches and abdominal pain?	4, *p**	0.25	0.5715	49.6 (29.3)	47.2 (29.0)	53.8 (25.0)	82.1 (24.9)	10.6	0.0000
What are the positive signs to check to confirm suspected severe preeclampsia?	5, *p**	0.27	0.6484	58.5 (30.2)	53.6 (30.0)	79.5 (21.4)	87.1 (18.6)	21.9	0.0000
What are the essential monitoring elements in case of severe preeclampsia?	6, *p**	0.35	0.7615	28.4 (27.2)	25.4 (26.0)	37.1 (24.6)	59.5 (32.5)	13.9	0.0000
What are the important and systematic actions to do after confirmation of severe preeclampsia?	4, *p**	0.38	0.7105	16.0 (24.6)	12.5 (22.0)	29.0 (28.6)	44.0 (29.9)	19.4	0.0000
What are the key elements to assess before repeat administration of magnesium sulfate?	3, *p**	0.47	0.7307	23.4 (33.3)	19.2 (31.1)	40.8 (34.2)	50.0 (42.9)	12.9	0.0000
What actions to take in case of a cardiopulmonary arrest after the administration of MgSO4?	2, *p**	0.36	0.5269	37.8 (39.7)	32.7 (38.6)	61.3 (36.7)	64.3 (36.3)	13.2	0.0000

Immediate care for the newborn (n=3)	**17, *p****	**0.46**	**0.7193**	**58.6 (20.3)**	**57.4 (20.8)**	**61.9 (17.6)**	**72.4 (11.3)**	**4.3**	**0.0141**
What are the systematic elements of newborn care immediately after birth?	8, *p**	0.22	0.6944	62.1 (26.0)	60.7 (26.4)	65.6 (23.6)	76.8 (20.7)	3.01	0.0506
What are the essential and systematic steps of birth asphyxia treatment?	6, *p**	0.19	0.5769	61.3 (26.5)	58.8 (26.4)	70.0 (23.0)	83.3 (23.6)	8.58	0.0002
What is the systematic approach of PMTCT?	3, *p**	0.16	0.3705	52.5 (23.2)	52.7 (23.6)	50.0 (20.0)	57.1 (24.2)	0.52	0.5965
Overall score (n=19)	**115, *p****	**0.48**	**0.9452**	**46.6 (19.3)**	**44.0 (18.9)**	**55.7 (15.6)**	**69.9 (16.7)**	**18.7**	**0.0000**

Table 5.3 contains the ANOVA results from the EmONC clinical skills exam. In total, the exam comprised six skill subsets, 19 questions, and 115 response items. The items correlated positively internally within each question and externally between questions and skill subsets. Reliability tests proved internal consistency across question and skill subset items. I reported the overall percent mean score on each question, each skill subset, and the overall score on the whole exam. Results are presented for all respondents (column 4) and for each type of provider (columns 5-7). I also reported significance level of the mean score differences between professionals (column 9).

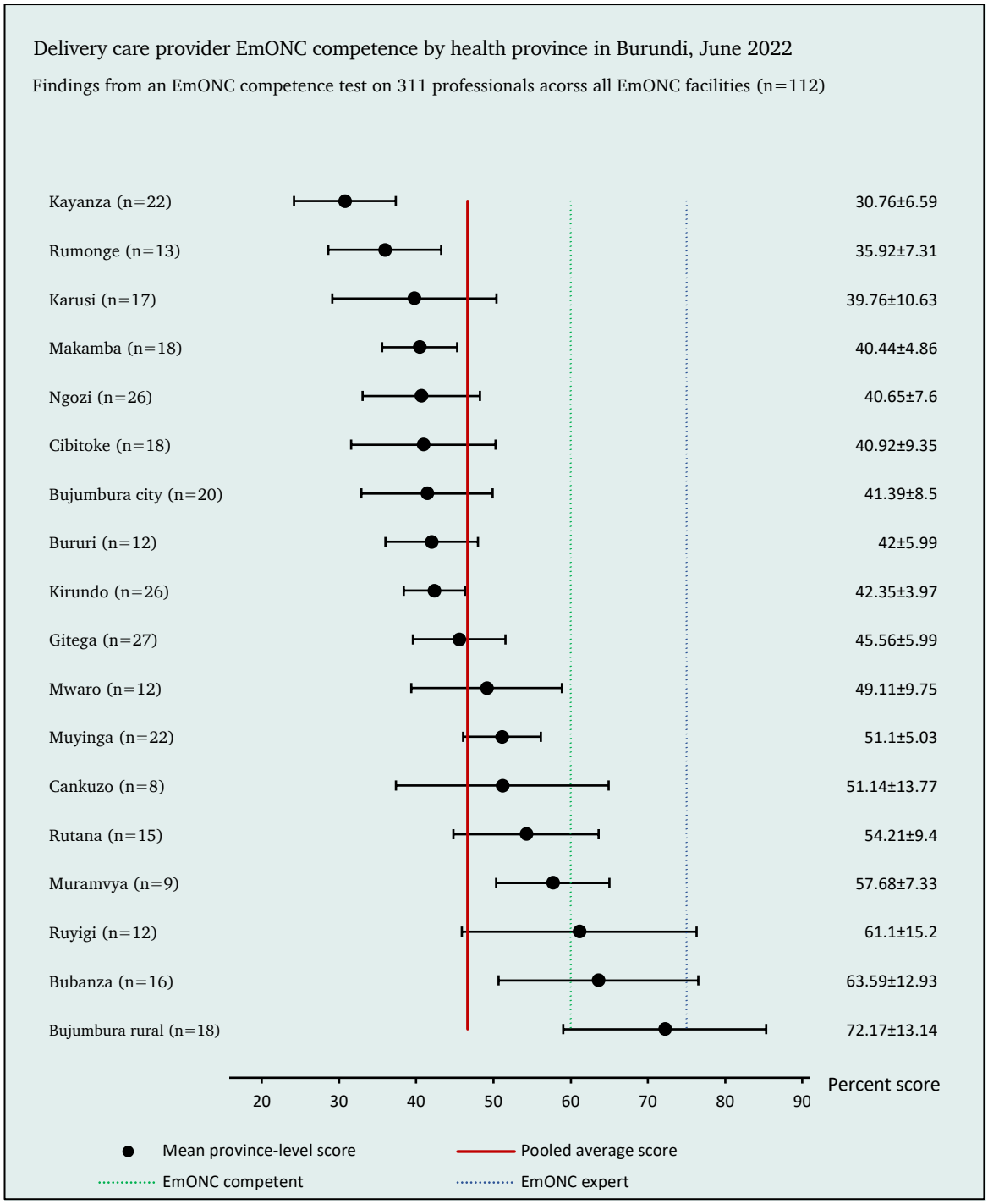


Figure 5.1 illustrates the average EmONC competence test scores at provincial level using total raw scores (out of 115 items corresponding to 115 maximum possible score). The Figure demonstrates provinces with poor EmONC performance in descending order. I highlight the national-level average score in red (pooled average score is around 48%) and provinces that achieved 60% (competent level) and 75% (expert level) on this EmONC competence test.

5.3.2. Difficulty of clinical vignettes and vignette items

Findings of the item difficulty analysis are summarised in Tables 5.2 and demonstrate that response items covered a wide difficulty spectrum, with the first item being the easiest (b_1 = —3.08) and item 74 the most difficult (b_{74} = 2.58). The first clinical vignette concerned labour monitoring and suggests that averagely competent respondents (i.e., those with θ in the vicinity of zero) would correctly respond to 17 out of 20 items. Similarly, averagely competent professionals would correctly answer 70% of the immediate newborn care items (vignette 5). The hardest EmONC vignettes are the management of fever and malaria (vignette 2), postpartum haemorrhage (vignette 3), and hypertensive disorders (vignette 4). Generally, any delivery care provider would require a high level of competence ($\theta > 0$ and often $\theta > 1$) to correctly answer the majority of items pertaining to care of these maternal complications.

Overall, any provider would require an extremely high underlying competence level ($\theta > 2.8$ on a standard ± 4 scale) to score 100%. I use Figure 5.2 to illustrate the levels of difficulty of items along with the levels of provider competence θ needed to succeed on vignette 1 items. On the whole, delivery care professionals in my sample would need θ in the neighbourhood of 1.4 (on ± 4 scale) to correctly answer the full set of labour monitoring items. Those with θ in the vicinity of zero would fail the fifteenth item (routine examination of the placenta and membranes during the third stage labour), the second item (monitoring on cervical dilation during labour), and the tenth item (checking proteinuria of labouring women).

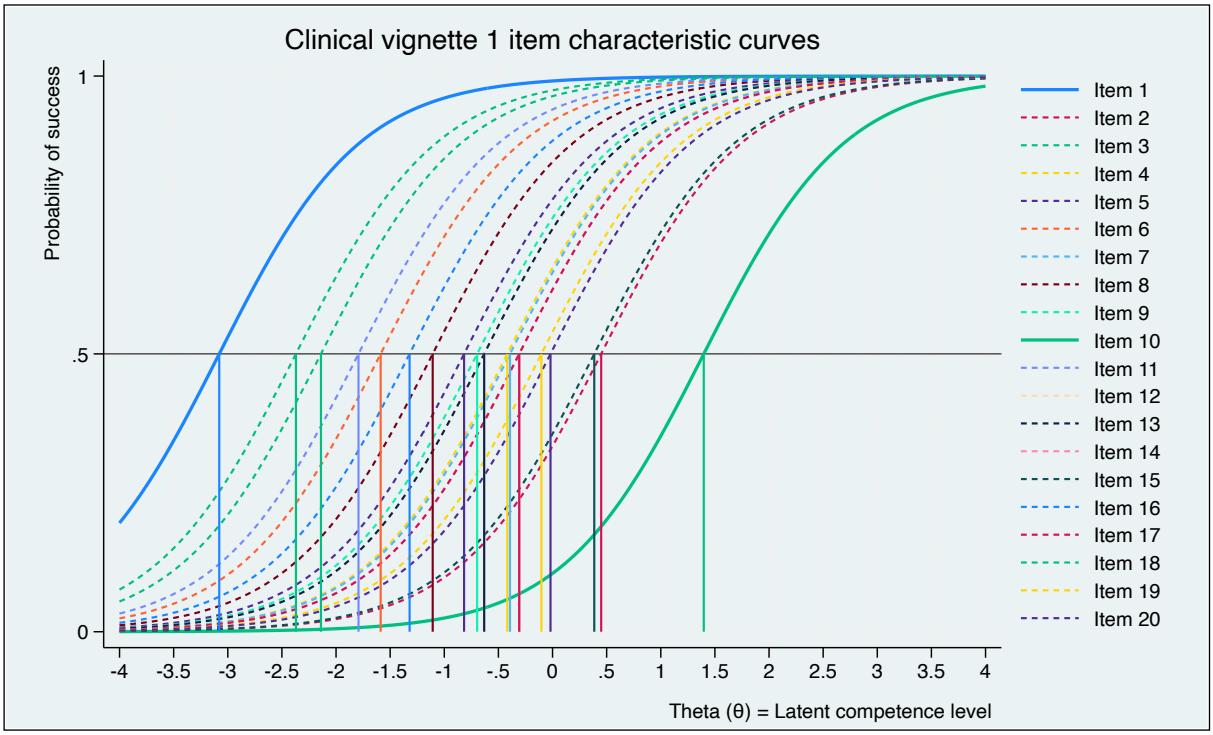


Figure 5.2 is the item characteristic curve of vignette 1 items (n=20). The horizontal axis represents the latent competence (θ) and the vertical axis is the probability of success on an item which is a function of both θ and the item difficulty b. The vertical lines represent the level of θ corresponding to 0.5 probability of success. Any level of θ below this threshold implies lower likelihood of success: if θ > b; Pr(success = 1|0) —> 1 and if θ < b; Pr(success = 1|0) —> 0. For example, professionals with θ in the vicinity of zero would succeed on 17/20 items situated on the left side of the vertical line θ = 0 and fail item 15 (routine examination of the placenta and membranes during the third stage labour), item 2 (monitoring on cervical dilation during labour), and item 10 (checking proteinuria of labouring women) whose curves are on the right side of the vertical line θ = 0.

5.3.3. Predicted EmONC competence test success rates

The expected success rates on the whole EmONC competence test if it were administered an infinite number of times are illustrated using Figure 5.3 and vignette-specific scores are summarised in Table 5.4. Keeping in mind that θ varies from —4 to +4, the combined analysis (shown in Figure 5.3a) demonstrates that the above-average professionals (those with θ slightly above 0) are predicted to score 55.7 on the whole 115-item test, or an integer score of 55/115 or more items. Using the standard critical threshold for $\alpha = 0.05$, the graph demonstrates that we can expect 95% of randomly selected professionals in EmONC facilities of all qualifications combined to score between 14 and 98/115 items. Medical doctors (i.e., Figure 5.3b) with θ of 0 would pass 71/115 or more items (95% range 30 to 96 items) while average midwives (i.e., Figure 5.3c) and nurses (i.e., Figure 5.3d) are predicted to score 65 and 52/115 or more items, respectively.

Regarding performance specific to each clinical vignette, Table 5.4 shows that the average professionals would score 13/20 items on labour monitoring, 4/13 items on fever and severe malaria management, 17/41 items on the management of postpartum haemorrhage, 8/24 items on the management of severe preeclampsia and eclampsia, and 10/17 items on the management of neonatal asphyxia and the provision of PMTCT services. Similar to the overall score, expected scores in individual vignettes consistently increase with higher qualification except for neonatal resuscitation and PMTCT in which all types of professionals seem to perform comparably. The predicted θ values in Figure 5.4 support the between profession differences with doctors having mean $\theta = 1.13$ (SD = 0.88), midwives mean $\theta = 0.40$ (SD = 0.84), and nurses mean $\theta =$ —0.12 (SD = 0.95).

Importantly, results in Table 5.4 revealed substantial gaps in EmONC competence within the same provider category, which corroborates with results of summated scores in Table 5.3. For instance, these results indicate that we would expect some doctors to correctly perform only 2 of the 24 recommended clinical tasks to manage severe preeclampsia and eclampsia while others would handle up to 20 (83%) care items. Similarly, we would expect some nurses to fail the whole set of items relating to clinical management of severe preeclampsia and eclampsia while others would correctly achieve 19/24 of these care items.

	Percent mean score	**Predicted success rate**			
		Overall	Doctors	Midwives	Nurses
V 1. Woman in labour (n=20)	64.3 (34.4–94.1)	13 (4–19)	15 (3–17)	15 (8–19)	13 (4–19)
V 2. Fever and severe malaria (n=13)	36.5 (15.7–57.3)	4 (1–9)	7 (2–11)	4 (2–8)	4 (1–9)
V 3. Postpartum haemorrhage (n=41)	45.4 (23.5–67.3)	17 (2–33)	25 (7–35)	22 (5–36)	17 (2–33)
V 4. Severe preeclampsia or eclampsia (n=24)	35.6 (11.5–59.7)	8 (1–20)	14 (2–20)	12 (3–20)	7 (0–19)
V 5. Neonatal asphyxia and PMTCT (n=17)	58.6 (38.3–78.9)	10 (3–15)	11 (7–13)	11 (4–15)	10 (3–15)

Table 5.4 In the first column of the results section, we summarise the overall mean scores and the corresponding 95% Confidence Intervals (CIs) in parentheses obtained from raw scores. Subsequent columns summarise the predicted success rates for each vignette (overall and by provider type) for the averagely competent professionals (i.e. those with $\theta = 0$) and the corresponding 95% CI success rates in parentheses assuming a countless repeat of the test administration.

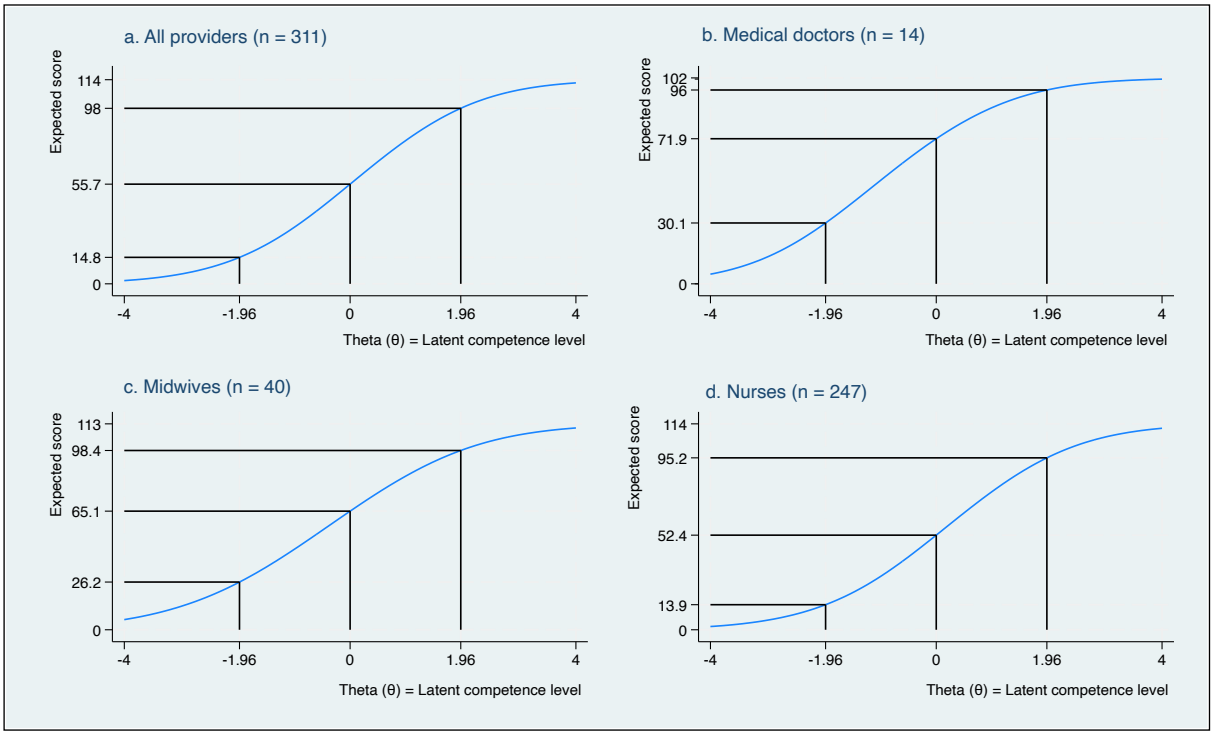


Figure 5.3 illustrates the Test Characteristic Curves (TCC) which predict the 'true score' as function of different levels of the latent competence (θ). The horizontal axis represents θ and the vertical axis is the predicted number of successes out of the total number of response items (n=115). We illustrate the predicted combined success rates (Figure 2a) and by provider type (Figures 2b-d) and use 95% critical values from the standard normal distribution (z = ±1.96) to predict the expected success rates of random samples of different types of deliver care professionals. We also predict the expected successes of averagely competent professionals (those with θ = 0).

To obtain the EmONC competence of each delivery care provider, I used the empirical Bayes means estimates which combine prior information about the latent competence θ with the likelihood function to obtain the conditional posterior θ distribution on ±4 scale. A comparison of true EmONC competence between delivery care professional groups is illustrated in Figure 5.4 and further substantiates the increase of EmONC competence with higher qualification. Expectedly, half of medical doctors have $\theta >$ 1.25 (mean θ = 1.13, SD = 0.88) while half of midwives have θ = 0.35 (mean θ = 0.40, SD = 0.84). Nurses have the lowest competence level with median θ = —0.25 (mean θ = —0.12, SD = 0.95). Interestingly, the overall mean competence appears to be significantly lower (mean θ = —0.00, SD = 0.98) compared to those of medical doctors and midwives separately and this is due to the predominant presence of nurses in our sample (257/311).

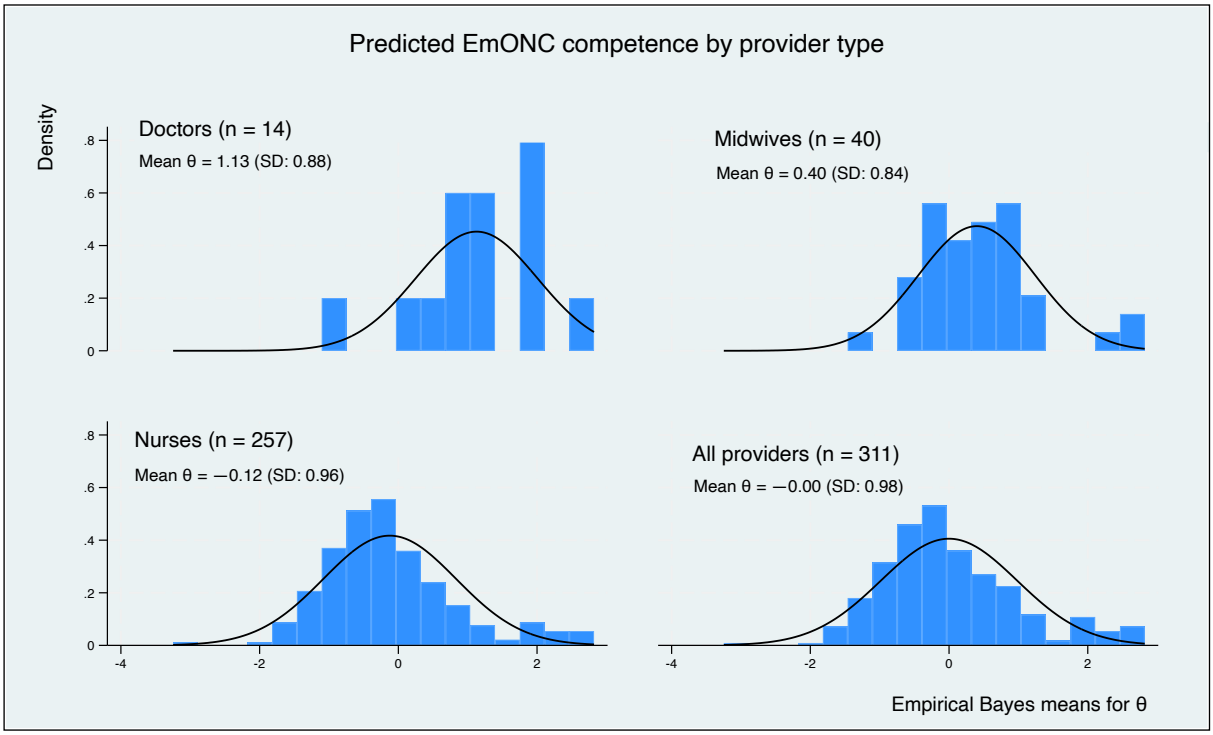


Figure 5.4 illustrates the distribution of the empirical Bayes means for the latent trait (θ) which produces posterior distribution using prior information about θ and the likelihood function (actual test scores) by provider category. Overall, this figure corroborates with findings of the one-way ANOVA test (Table 5.3) that used total raw scores and proves that θ increases with higher qualification. The pooled θ approximates zero and is normally distributed. Particularly focusing on doctors and midwives (top row), this Figure shows that some doctors and midwives have very low competence while others are very competent and both categories are outliers. Also, the graph of nurses (bottom left) proves that there are fewer nurses who demonstrate having competence comparable to midwives and doctors (e.g., those with $\theta > 1$).

5.3.4. Determinants of EmONC competence

The multivariable linear regression indicated that EmONC competence increases with higher qualification and with previous EmONC training as shown in Table 5.5. In a model that excluded doctors, the effect of facility type was not apparent, suggesting that midwives and nurses performed similarly in both CEmONC and BEmONC settings. Provider's sex and age, and the type of employment and length of maternity experience have no statistically significant effect on EmONC competence. Interestingly, EmONC training does not seem to significantly impact EmONC competence of medical doctors and midwives but does appear to have an effect in nurses.

	Coefficient (95% CI)	S.E. (Bootstrap)	P-value
CEmONC facility (base = BEmONC)*	**0.29 (0.07 – 0.50)**	**0.11**	**0.007**
CEmONC facility (base = BEmONC)**	0.19 (—0.02 – 0.41)	0.11	0.078
CEmONC facility (base = BEmONC)***	0.11 (—0.12 – 0.35)	0.12	0.344
Midwives (base = nurses)	**0.52 (0.24 – 0.81)**	0.16	**0.000**
Doctors (base = nurses)	**1.25 (0.77 – 1.73)**	0.28	**0.000**
Male sex (base = female sex)****	—0.10 (—0.32 – 0.11)	0.11	0.342
Partial time employment (base = full-time)	0.29 (—0.33 – 0.92)	0.32	0.360
EmONC training (base = no training)	**0.33 (0.12 – 0.55)**	0.11	**0.002**
Doctors who received EmONC training†	0.27 (—0.65 – 1.18)	0.47	0.565
Midwives who received EmONC training†	—0.03 (—0.54 – 0.48)	0.26	0.905
Nurses who received EmONC training†	**0.37 (0.14 – 0.60)**	0.12	**0.002**
Age in years (continuous)	—0.00 (—0.03 – 0.02)	0.01	0.724
Age in years squared	—0.00 (—0.00 – 0.00)	0.00	0.121
Number of previous deliveries (continuous)	0.00 (—0.00 – 0.00)	0.00	0.639
Number of previous deliveries squared	—0.00 (—0.00 – 0.00)	0.00	0.064

Table 5.5 summarises findings of the linear regression model of EmONC competence score (predicted using the empirical Bayes means) as the dependent variable and facility type, qualification, sex, type of employment, history of EmONC training, age, and the number of deliveries performed before as independent variables. Further, we examined the effects of qualification and EmONC training separately and then combined by provider type. We used 10,000 bootstraps to address heteroskedasticity of residuals and highlighted significant coefficients in bold. *The model includes all providers. **The model includes midwives and nurses. ***The model includes nurses only. ****With the aim to minimise gender and qualification bias (more men are doctors), we excluded doctors from sex variable. Coefficients are θ and vary from -4 to +4. †Bases are professionals who did not receive EmONC training before.

5.3.5. EmONC competence test validity

Results of the test information function are demonstrated on Figure 5.5 which plots the information and standard error curves to diagnose how well the designed clinical vignettes are suited to estimating EmONC competence over the whole range of competence levels of delivery care professionals. Mathematically and graphically, the maximum information conveyed (i.e., the maximum precision) corresponds to the lowest standard errors. Inspection of this Figure 5.5 shows that the test gives the maximum information for θ in the neighbourhood of zero and remains high for the competence range $\theta \pm 0.5$. Within this range, EmONC competence examined using these clinical vignettes is estimated with greatest precision. Otherwise, the test validity decreases as the competence level departs from this range and the amount of information approaches zero at the extremes of the competence scale. Therefore, these

clinical vignettes are suited for test consumers who have a competence level (θ) such that —0.5 < θ < 0.5. In my sample and generally for Burundian delivery care professionals in EmONC facilities, 137/311 (44%) test takers of whom 1/14 (7%) medical doctor, 22/44 (55%) midwives, and 114/257 (44%) nurses would fall in that competence range and this implies that the instrument is believed to obtain precise EmONC competence estimates among midwives and nurses.

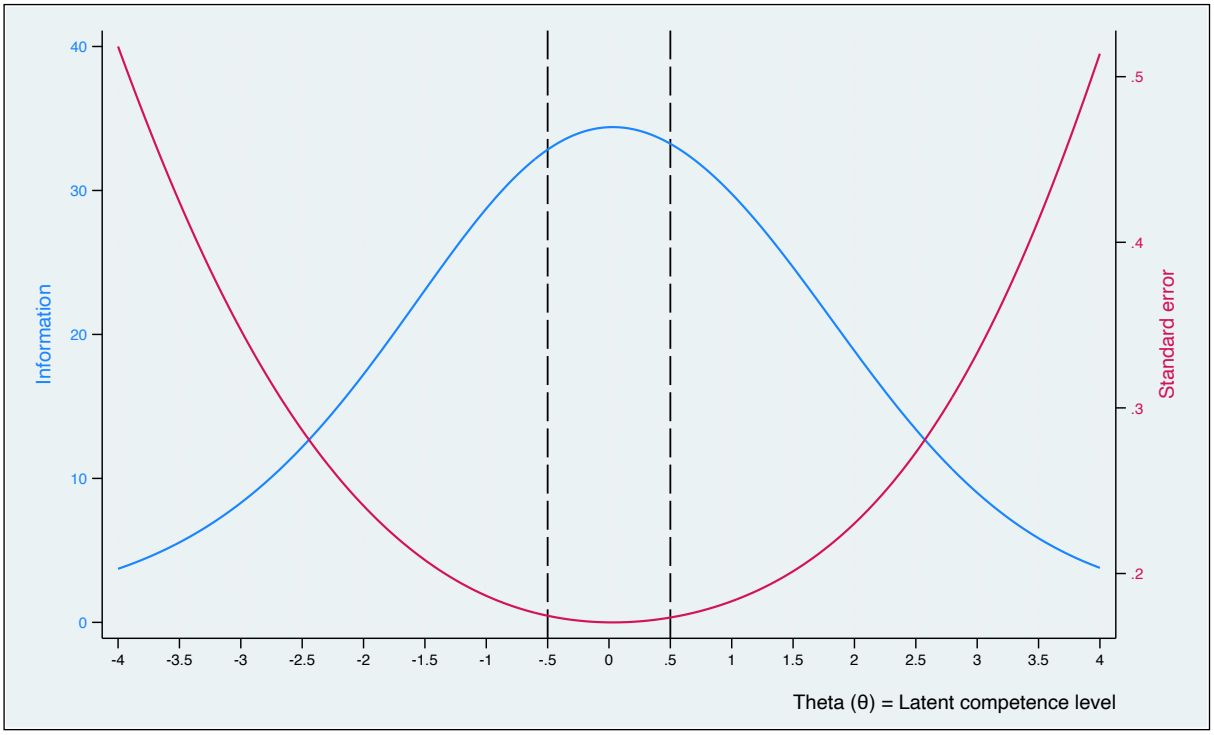


Figure 5.5 Test Information Function and validity of the EmONC competence test instrument. This Figure results from the Test Information Function (TIF) analysis and illustrates the levels of θ corresponding to the maximum information. Looking at the standard error curve in red plotted against the right scale, we observe that the amount of information provided by the test at θ_i is inversely correlated to the precision with which EmONC competence is estimated at that point. The maximum information (i.e., the maximum precision) lies within the vicinity of θ of zero and remains around 35 between $\theta \pm 0.5$. This instrument is therefore suited for health workers with competence level (θ) such that —0.5 < θ < 0.5.

5.4. Discussion

Given the overall aim of the thesis to inform Burundian policymakers on structural and workforce challenges facing Burundian EmONC facilities and to further guide strategic investments in strengthening the EmONC network; and further building on the budget needs estimated in Chapter 3, it was important to assess whether Burundian delivery care providers in EmONC facilities possess the necessary competence to manage

maternal and neonatal complications effectively. This analysis was particularly valuable for identifying specific and targeted training needs, which have significant budget implications, especially considering that EmONC training has been shown to be costly as detailed in the Supplemental material 12.

Thus, considering the growing impetus to capture competence of healthcare workers[150,325] which is indispensable for achieving quality-adjusted service coverage and hence quality care,[205] I show in this Chapter how a psychometric approach (i.e., the IRT) to examine competence of health workers can be used to deepen analysis compared to traditional and classical test theories (e.g., summated scales and component and factor analyses) that are the most popular forms of competence analysis in healthcare.[305-307,326,327] In fact, classical competence assessment approaches assume that test takers would achieve exactly the same scores if the test were to be administered repeatedly and fail to discern and discriminate between less and more difficult test components, and do not predict true competence which is essentially an unobservable trait.[328,329]

I used the EmONC competence test conducted on 311 delivery care providers across all Burundian EmONC maternities to demonstrate the applicability of the IRT model, a probabilistic model proposed by Rasch in 1960,[330] and how it overcomes the above limitations of classical test theories while providing a more comprehensive data appraisal.[308]

While my main objective consisted in applying IRT to medical data rather than documenting its added value over existing tools, many authors have comprehensively explored and empirically proven this superiority.[308,313] For instance, Kate Mitchell-Parker et al. (2018) demonstrated how various IRT models can enable precise measurement of individuals along the instrument by placing them and the test items on the same log-odds interval scale.[308] Moreover, a specific study that compared factor analysis against the IRT model has established that the latter model offers better fit in data applications involving individual rating particularly if there are many parameters and items.[314] The IRT models enable us to assess and quantify individuals' abilities or traits accurately by positioning both the test takers and the best questions on the same measurement scale which is based on the log-odds, thus allowing for a consistent and

precise comparison of the person's ability level relative to the difficulty of the test items.[308]

In my study, I discovered that both raw statistics and the IRT model produce comparable learnings with the IRT model offering several additional, deeper insights that facilitate a more refined and accurate understanding of individual's performance as illustrated in Tables 5.2. They indicate that we would generally expect considerably smaller proportions of participants to correctly respond to the most difficult test items (e.g., about 6% of participants would alert a medical specialist during the management of abundant postpartum haemorrhage or an incomplete/unsafe abortion which both have the highest b_j coefficients) while the vast majority of test takers would correctly answer the easiest items (e.g., 98% of participants would monitor fetal heart rate during childbirth and this item has a difficulty level b_j = —3.07 on ± 4 scale). The ANOVA test and the TCC and corresponding Bayes means estimates all confirmed the effect of higher qualification on EmONC competence. Indeed, according to ANOVA findings in Table 5.3, nurses achieved 44% on the EmONC competence test, midwives 56%, and doctors 70% and the TCC (see Figure 5.3) indicated that random samples of doctors, midwives, and nurses would score 62% (71/115 successes), 57% (65/115 successes), and 45% (52/115 successes) respectively. Although these findings are similar, I argue that IRT predicted scores are most accurate as they draw on simulations of an infinite repeat of the EmONC test administration.[312]

Furthermore, in addition to the ANOVA estimates which are percent scores based on correct answers, the Rasch model offered an extra layer of understanding of the latent EmONC competence which is fundamentally different from obtained scores and is estimated by updating prior information (i.e., the underlying EmONC competence) with the likelihood function (i.e., the actual test scores). Expectedly, I found substantial evidence in Figure 5.4 that medical doctors have higher EmONC competence than midwives on average (medical doctors' mean θ = 1.13, SD = 0.88 on θ ±4 scale versus mean θ = 0.40, SD = 0.84 among midwives) while nurses demonstrated the lowest competence level (mean θ = —0.12, SD = 0.95). However, since the SD values reflect the degree of variability in competence scores within each cadre category, my findings suggest that although doctors have a higher average competence, there is considerable variation with some doctors likely scoring much lower, potentially overlapping with the

scores of midwives and nurses. This variability was observed across all cadres indicating that EmONC competence can differ widely among providers within the same category. Part of this disparity may be attributed to differences in background training such as variations in performance between professionals trained in private versus public institutions.[331] Another possible explanation of this wide dispersion is the small sample sizes particularly among doctors and midwives as this can affect statistical estimates.

One of the most policy relevant findings from this Chapter concerns the routine EmONC training which is heavily supported by the Burundian MoH and key MNH partners principally UNFPA, WHO, UNICEF, JICA, Pathfinder, MNH professional associations, and various local research and service delivery institutions with considerable government and partner financial commitments made over the past eight years (see Supplemental material 12).[285] I found that its impact is particularly notable among nurses as those who received it had on average about 0.37 (95% CI: 0.14 – 0.60) higher EmONC competence on $\theta = \pm 4$ scale. Conversely, even though my samples of doctors and midwives are small and unevenly split between those who received EmONC training and those who had not thus limiting the representativeness and generalisability of findings, I observed that the EmONC training does not have a statistically significant impact on the overall competence of medical doctors and midwives probably because the latter two professional categories receive substantial training in maternal and newborn care complemented with significant hospital internships in maternity and neonatology as part of their education. Based on the previous, I posit that focusing the EmONC training on nurses would be more efficient, allowing therefore to save a considerable amount of budget that could be redirected to other EmONC needs. Moreover, nurses constitute the largest workforce stock available in Burundian EmONC facilities.

Regarding the instrument validity which I tested using Figure 5.5, I proved that the EmONC clinical vignettes that I developed together with stakeholders, that draw on the standard EmONC training for all delivery care professionals irrespective of their education levels, are suitable to examine EmONC competence of nurses and midwives specifically. Factually, even though my sample included fewer medical doctors (14/311), statistical evidence suggests that my instrument would fail to detect precise EmONC competence of approximately 93% of random samples of Burundian medical

doctors specifically those working in EmONC maternities. Therefore, a combination of the competence test results and the instrument validity suggests that medical doctors should receive a specifically designed EmONC competence test. Practically, nurses principally to a lesser degree should be prioritised for training and this has significant implications for the EmONC training strategy and budget.

There are some analytical limitations to acknowledge. First, my focus on the one-parameter IRT model (i.e., the Rasch model which is limited to the difficulty parameter) didn't allow me to explore the discrimination and guessing parameters which is possible with a three-parameter IRT model. Second, my analysis relied on small sample sizes of medical doctors (14/311) and midwives (40/311) thus offering less information about these professionals, but this is a general depiction of Burundian healthcare workforce distribution. This sample issue was further improved by predicting an infinite number of test repeats, an approach that underpins the IRT model. Finally, the clinical vignettes did not test competence linked to obstetric surgery (e.g., hysterectomy and caesarean section) that might better discriminate between doctors. It was not practically possible to design a clinical vignette to examine various surgery procedures such as caesarean section and haemostatic hysterectomy but my assumption is that if all delivery care providers could offer quality care for all maternal and neonatal clinical scenarios even with the exception of surgery, many maternal and neonatal lives could be saved. However, in the same perspective, I would recommend conducting a specific study to examine doctors' competence linked to obstetric surgery.

5.5. Conclusion

In this Chapter, I used a statistical method less commonly employed in health that rests upon the Bayesian concept to extend the common frequentist analyses of clinical competence of health workers. I demonstrated that IRT models reinforce findings of classical statistical theories namely summated scores while offering extra layers of understanding and enabling us to validate new or update existing competence test instruments tailored to particular categories of health workers. Particularly, I went beyond routine analytical approaches and illustrated the importance of capturing difficulty levels of various test components; proving the feasible computation of these analyses using commonly used and widely available statistical packages (e.g., STATA

18). Furthermore, I highlighted the major inherent assumptions underpinning competence assessment methods and showed how IRT concepts fully accommodate these assumptions. For instance, I illustrated that IRT permits prediction of the true scores assuming an infinite repeat of test administration and to update the latent competence (i.e., prior ability) using actual test scores (i.e., the likelihood function) to predict the true competence (i.e., posterior ability). I consistently found that Burundian delivery care professionals in EmONC facilities generally have poor EmONC competence although medical doctors proved to be better than midwives and nurses. I also found that Burundian standard EmONC training does not statistically augment EmONC competence of doctors and midwives and this has meaningful policy implications to target the EmONC training budget or to redesign different EmONC training modules for each type of professional (i.e., medical doctors separately from midwives and nurses).

Chapter 6. Prioritising EmONC workforce investments

This Chapter contains some of the content of a manuscript under review in Health Policy Open (Ref: HPOPEN-D-25-00075: Prioritising human resource investments in a context of scarce resources: exploring options for the Burundian EmONC network). This manuscript is provided as Appendix 5.

In Section 1.7 of the Introduction Chapter I outlined the rationale for focusing my study on human resources for health (HRH) and in Chapter 4, I quantified both human and physical resource deficits assessed against three different benchmarks and further estimated the budget needed to address these gaps in each EmONC facility and across the EmONC network. While supplying physical resources such as equipment is relatively straightforward, recruiting and retaining qualified human resources always pose significant challenges. Moreover, given that Burundi is a low-income country, this country may struggle to mobilise sufficient funds to fully address the estimated staffing requirements across the EmONC network.

In response to the above issue, I developed a framework centred on human resources aimed at exploring options for facility prioritisation with an overall goal to assist Burundian policymakers in identifying a subset of facilities that might be a priority for workforce investment, particularly in scenarios where securing the full budget to address systemic capacity issues proves unfeasible. This Chapter presents findings from the prioritisation framework and suggests a subset of facilities could be considered for priority investment. The Chapter begins with a brief background to contextualise the need for facility prioritisation, followed by a detailed description of my prioritisation framework in the methods section, and concludes with the results and discussion. First, I summarise key findings in Box 6.1.

Box 6.1 Key findings from Chapter 6

Existing knowledge

- Provision of quality EmONC could enable LMICs to deliver on the MNH agenda 2030. However, low income countries such as Burundi are struggling to deliver quality care because of scarce and poorly directed resources, especially human resources. Burundi's network of 112 EmONC facilities has severe workforce deficits but addressing all of these may not be possible.

Methods

- I conducted a cross-sectional survey of all Burundian EmONC facilities (n=112) documenting available human resources and collated annual data on deliveries, maternal complications, and health outcomes covering 2021. I developed a categorisation approach based on these data and explored the additional value of maternal mortality as a categorising variable with funnel plots, including use of readjustments for overdispersion and Winsorization.

Key findings

- I show that the volumes of normal and complicated deliveries in a Burundian EmONC facility are not aligned with its status as a basic or comprehensive emergency obstetric and neonatal care facility, a finding that also points to failures in the referral system. I further show, using routine data that a subset of facilities with high numbers of normal and complicated deliveries that are very poorly staffed can be identified. Together these 24/112 facilities manage 30% of all deliveries, 35% of complicated deliveries but have only 15% of available staff and could be prioritised for investment in the face of scarce resources. Available data on maternal mortality was very variable and not useful for facility prioritisation.

Policy and practice implications

- This analysis shows how routine data might be better leveraged to support policy makers' decisions to improve efficiency and potentially effectiveness of human resource investments by demonstrating the application of this approach to Burundi's EmONC network. The prioritization framework could help inform policy makers to better direct limited resources, an approach of potential relevance to other LMICs.

6.1. Background

Although the Burundian EmONC network represents a clear and rational policy objective, I identified in Chapter 4 substantial resource deficits even when compared with modest national resource recommendations.[113,318] In fact, total resource deficits across the 112 EmONC facilities amounted to approximately 162 medical doctors, 1005 midwives and nurses, 132 delivery rooms, and 678 and 156 maternity and newborn care beds respectively amongst others, with deficits unevenly distributed across facilities.[318] To address these deficits, I showed that an investment amounting to approximately US$ 32.9 million would be required to cover 5 years, representing an increase in the Burundian total health budget of about 6% annually.[318] However, the Burundian total health budget amounts to approximately US$ 112.4 million (i.e., Burundian francs, BIF 2,228.7 billion) per year which corresponds to about 9.6% of the total government budget[157] with health expenditure of BIF 25,512 (about US$ 9) per capita. Burundi may not, therefore, successfully mobilise such a large budget increase (i.e., US$ 32.9 million) to cover these basic needs in the near term. In this Chapter, I explored whether some facilities might be targeted for investment with a view to optimising use of scarce resources with a continued focus on equity.

To do this, I developed and implemented an approach to prioritise facilities based on prevailing workloads, existing resources, and maternal mortality. Initially, I examined whether the official B/CEmONC facility designation is meaningful by exploring the relationship between facility type, workload and numbers of women with delivery complications, hypothesising that BEmONC facilities with fewer resources should deliver fewer women with complicated deliveries. Absence of these expected relationships prompted me to develop a prioritization framework to identify facilities with high delivery workloads and greater numbers of complications but with fewer resources. Such facilities I posit, if they can be accurately identified, may be priorities for investment. As part of this work, I further explored the relationship between maternal mortality, workloads, and human resources and demonstrated empirically that annual reported mortality is likely to be an unreliable criterion to prioritise facilities in Burundi.

6.2. Study design and conceptual framework

6.2.1. Study design and data description

I collected EmONC facility records of deliveries, maternal complications, and deaths across all 112 facilities for the year 2021. Maternal complications comprised prolonged or labour dystocia, post abortion complications, maternal infections, postpartum haemorrhage, severe preeclampsia or eclampsia, and uterine rupture. I focused on maternal conditions as accurate determination of newborn outcomes was not possible from routine facility records. In June and July 2022 I assessed the infrastructure available and the presence of delivery care professionals namely doctors, midwives, and nurses specifically assigned to provide maternity services using a survey approach described in detail elsewhere (see details in Section 3.6 of the Methods Chapter).[332]

6.2.2. Examining the EmONC facility standard classification

I showed in Chapter 4 that the Burundian EmONC policy indicates that BEmONC facilities should have 1 delivery room with 2 delivery tables and 8 maternity beds, 1 midwife and 2 nurses. CEmONC facilities are supposed to have 2 delivery rooms with 4 and 22 delivery tables and maternity beds respectively, a doctor and 4 midwives and 9 nurses.[318,333] This basic and comprehensive facility status is intrinsic to the Burundian EmONC network design where larger facilities providing a full set of assisted delivery services including caesarean sections support peripheral smaller facilities and receive referrals from them. To examine whether this standard EmONC classification into B/CEmONC facilities holds, I explored statistically and graphically the relationships between facility type and deliveries and complications expecting that CEmONC facilities should perform more deliveries and manage considerably more complications than BEmONC facilities. To confirm the BEmONC versus CEmONC categorization, I further examined whether some BEmONC facilities usually perform 'signal functions' specific to CEmONC facilities namely caesarean sections and blood transfusion.[42]

6.2.3. Conceptualising priority EmONC facilities

Next, I developed a logical framework for grouping EmONC facilities based on actual deliveries, complications, available human resources, and maternal mortality as conceptualised in Figure 6.1 to isolate possible sites for priority investment assuming that Burundi cannot raise in the short run the estimated US$ 32.9 million to cover the network-level EmONC needs.[318] To do this, I created for each input variable (i.e., deliveries, complications, human resources, and mortality) high, moderate, and low levels and combined these criteria to identify high priority and priority facilities as demonstrated in Figure 6.1. Conceptually, 'high priority' EmONC facilities are those managing high delivery volumes together with high levels of complications but having few or moderate human resources. 'Priority' facilities have moderate workloads and complications with few human resources. Although mortality was an unreliable criterion to classify facilities in my case (see below in the Results section), it was included in the framework to demonstrate conceptually (high) priority facilities where an investment might accrue more health benefits (i.e., save more lives) in situations where high quality, reliable mortality data is available.

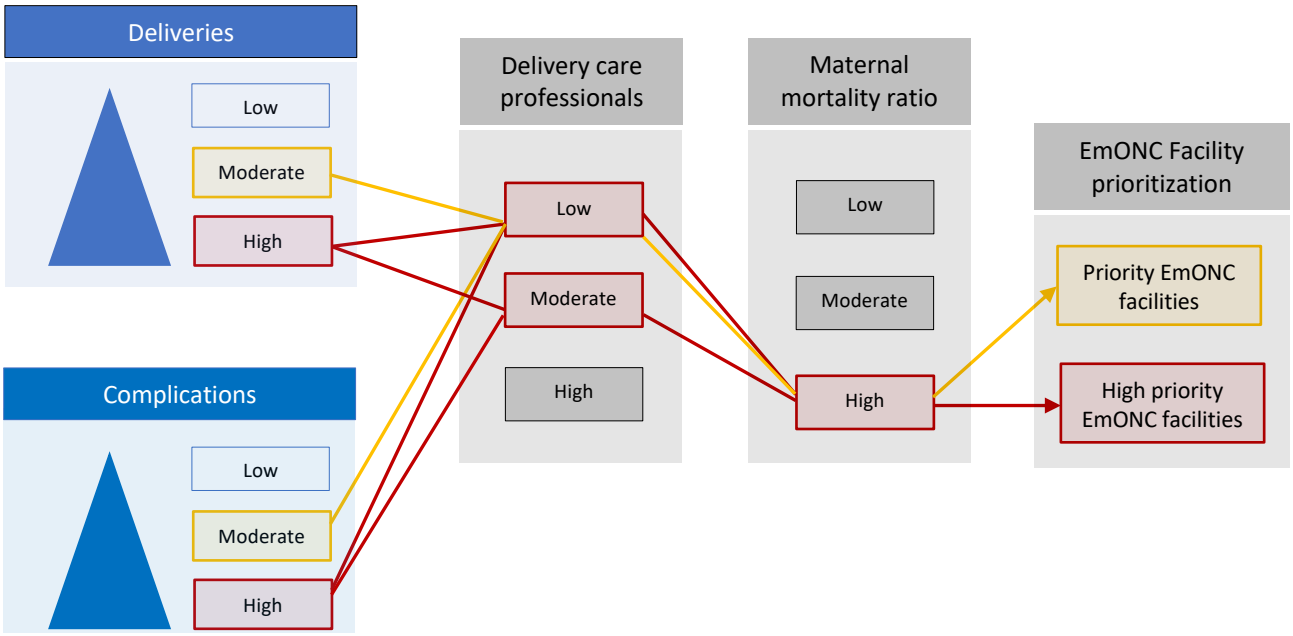


Figure 6.1 Conceptualisation of EmONC priority facilities. 'High priority' facilities i.e., those worthy of a priority investment to avert maternal deaths are those facing high deliveries and correspondingly high maternal complications with low or moderate levels of human resources and where maternal mortality is highest. EmONC facilities with moderate workloads, fewer human resources, and more deaths are considered as 'priority' investment facilities.

6.3. Data analysis

6.3.1. Statistical analyses

Before facility categorisation as schematised in Figure 6.1, I first explored statistically and graphically the distributions of deliveries and complications across all EmONC facilities; testing for normality. These basic explorations revealed considerable data variability better addressed with a statistical method to handle data overdispersion.

I used the overdispersion z-score method which is recommended for distributions when the influence of chance is variable or low and when sample sizes are highly variable across organisations.[1,334] This z-score method uses the standard deviation (σ_o) of observed data and identifies organisations lying at the edge of the distribution using $\pm 1.96\ \sigma_o$. I classified EmONC facilities in the negative and positive tails into low and high facility categories for my indicators of interest respectively and those within the 95% confidence interval into the moderate category. Further, I used the reliability (λ) test to confirm this classification (see Equation 1 of Box 6.2).[334] Without assessing reliability, it is difficult to assign an organisation to a particular category and to appraise the degree of resultant misclassification. Even though there is no commonly agreed reliability benchmark, the literature argues that more than half of flagged organisations using the overdispersion z-score method are misclassified if reliability is below 0.7.[335] In other words, reliability needs to reach at least 0.7 for 50% of units to be correctly classified. A reliability score of 0.9 or above indicates that chances of misclassification have almost been completely eliminated.[334] Using this approach to developing categories I created a matrix of facilities based on their high, moderate or low categorisation for the three parameters; delivery workload, numbers of delivery complications, and human resources.

Furthermore, I explored the use of maternal mortality as an additional parameter to categorise facilities using funnel plots which are a Statistical Process Control (SPC) method[2,336] used to study variability of performance indicators between institutions or areas and for identifying outliers.[337-339] Funnel plots detect outliers which are data points worthy of further investigation[340] by comparing the outcome metric (i.e., MMR

in my case) against a measure of its precision which typically is the sample size (i.e., total deliveries in my case) and horizontally superimposing the target and 95% (i.e., p-value 0.05 and 2 standard deviations) and 99.8% (i.e., p-value 0.002 and 3 standard deviations) lower and upper limits. These correspond to the standard deviations used in control charts to indicate that organisations are "not in control" and warrant further inspection.[1,337] Generally, units that lie within 2 standard deviations are tagged as "controlled", those lying between 2 and 3 standard deviations are "warning" while those outside 3 standard deviations are red flagged as "alarming" organisations.[1]

Box 6.2 Statistical approaches for EmONC facility classification: reliability and overdispersion

$$\lambda = \frac{\sigma_o^2}{\sigma_o^2 + \frac{\sigma_w^2}{\sqrt{n}}}$$

Equation 1

In my context, reliability λ refers to the Spearman Brown or inter-unit reliability which is a measure of how reliably different units can be distinguished, ranked, or classified based on the overdispersion method and ranges from 0 to 1. When reliability is low, it is difficult to distinguish amongst organisations. Statistically, Spearman Brown reliability is formally defined as the ratio between the true underlying variance, σ_o^2, and the within organisation variance, σ_w^2, and the sample size n as

$$\Phi = \frac{1}{I}\sum_{i=1}^{i=n} \frac{(y_i - \theta_o)^2}{g(\theta_o)}\zeta_i$$

Equation 2

Adjusting funnel plots control limits such that $\rho = \Phi\sigma$ where ρ corresponds to the new control limit and Φ is the overdispersion parameter. Where $g(\theta_o)$ equals σ^2 for known θ_o and for continuous y_i outcomes. I had a sample I units that I assumed all to be in-control and set ζ_i as the effective sample size. Consequently, $I = \zeta_i$. Empirical demonstrations of these assumptions have been comprehensively developed elsewhere.[1,2]

However, one major shortcoming of funnel plots is their inability to account for overdispersion.[341,342] To address this important setback, I readjusted control limits to account for this using empirically proven approaches such that $\rho = \Phi\sigma$ where ρ corresponds to the new control limit and Φ is the overdispersion parameter[1,2] (see details in Equation 2 of Box 6.2).

Finally, I used 2D charts to highlight 3 EmONC facility categories pertinent for policy attention or a priority investment. The first category comprises facilities with both high deliveries and complications and the second and third facility categories combine high deliveries and moderate complications and moderate deliveries and high complications respectively. I added a third criterion; human resources; to identify amongst these three categories facilities having low or moderate human resources flagging them as priority facilities (see Figure 6.1). For national policy makers I showed using the 2D chart where all 112 facilities lie in the overall, nine level categorisation approach highlighting those with relatively more human resources for their level of workload.

6.3.2. Sensitivity analysis

I also performed a range of sensitivity analyses informing the use of the above statistical methods to account for overdispersion in creating categories and employing funnel plots. Firstly, I performed structural sensitivity analysis by purposively excluding big hospitals with outlying numbers of human resources and EmONC facilities with zero maternal deaths hypothesising that this is contextually inaccurate. Indeed, it is less likely that an EmONC facility in Burundi records zero maternal deaths over a period of 12 months particularly since these facilities receive complicated referrals. Rather, deaths could be underreported as this may benefit facilities because of performance-based financial rewards. Secondly, I adjusted parameters by implementing one-sided MMR winsorization which is a data transformation procedure that recodes outliers of the distribution to less extreme values.[343] I did not perform two-sided winsorization because mortality cannot be negative and was found to be positively skewed with zero inflation. EmONC facilities that consistently remained outside the overdispersed control limits even after data winsorization and outlying facility removal were considered to be very concerning indeed.

6.4. Results

6.4.1. Facility functions are not aligned with EmONC standard classification

Contrary to expectations, the ratio of maternal complications to deliveries appears to be similar in BEmONC and CEmONC facilities (see Figure 6.2). BEmONC facilities are by design smaller and with more limited capacity and are hypothesised to have correspondingly lower workloads and infrequent delivery complications. In fact, some BEmONC facilities are busier than larger hospitals with for instance 11 BEmONC facilities reportedly performing five and more deliveries daily on average while on the other hand 10 and 21 CEmONC facilities reportedly performed fewer than 3 and 4 deliveries daily respectively. There was a more consistent difference with human resources as CEmONC facilities typically enjoyed more delivery professionals, although even within CEmONC facilities staffing did not necessarily correspond with workload. For instance, among BEmONC facilities handling approximately 1500 deliveries and 500 complications annually, staffing levels and skill-mix vary widely, a pattern also observed in CEmONC facilities (see Figure 6.2a and Figure 6.2b). Some CEmONC facilities managing up to 2000 deliveries and 500 complications annually might have between one to eight nurses and midwives assigned to provide these services and may be with or without a doctor. Interestingly, data also revealed that several hospitals employ more than 10 nurses and midwives to provide delivery services but have no designated doctor. Furthermore, contrary to both global standards and national guidelines, I identified three BEmONC facilities where a medical doctor performs caesarean sections and blood transfusions despite these procedures typically being reserved for higher-level facilities.

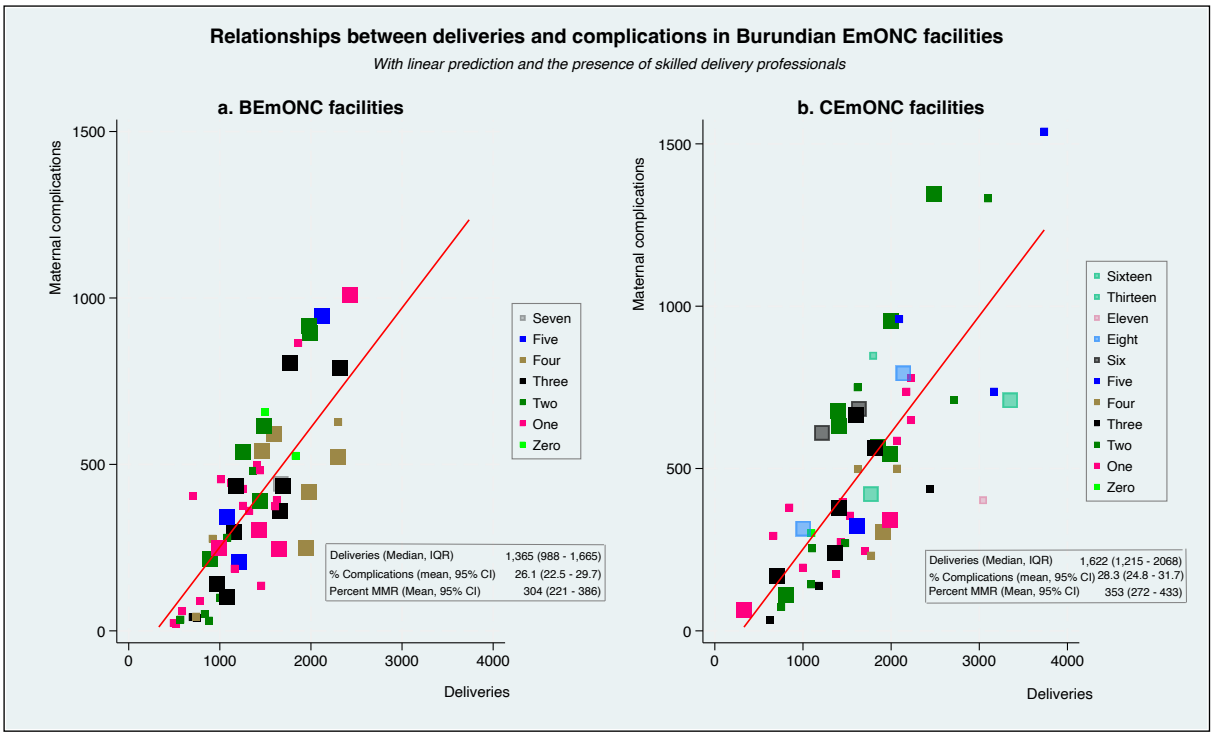


Figure 6.2 examines the relationships between deliveries and maternal complications with human resources by facility type. The symbol colour represents the number of midwives and nurses combined and the size corresponds to the presence or absence of a midwife in BEmONC facilities and that of a doctor in CEmONC facilities. Therefore, big markers in *Figure 6.2a* mean the presence of a midwife and that of a doctor in *Figure 6.2b*.

6.4.2. Variation in maternal mortality across EmONC facilities

Maternal mortality varied very widely across facilities and was thus unreliable for prioritising them. I demonstrated this by exploring its variation relative to workloads and human resources using funnel plots with various data transformations. This included adjustment of control limits using the overdispersion parameter, data winsorization, and controlling for outlying facilities. In Figure 6.3 I show that EmONC facilities record an average of about 380 maternal deaths per 100,000 deliveries. Before data transformation, the unadjusted funnel plot in Figure 6.3a suggests that most facilities lie outside standard control limits, implying that almost all Burundian EmONC facilities have special cause variation influencing MMR. Employing winsorization (see Figure 6.3b) reduces the number of facilities with apparent special cause variation influencing MMR with 26/112 (23.2%) appearing to have much higher than expected MMR. However, it can be seen that many facilities reported zero maternal deaths, even amongst the category with high workloads, high numbers of complications and lower

human resources and further efforts to adjust for variation did not provide a strong rationale for using MMR to prioritise facilities (see Figure 6.4).

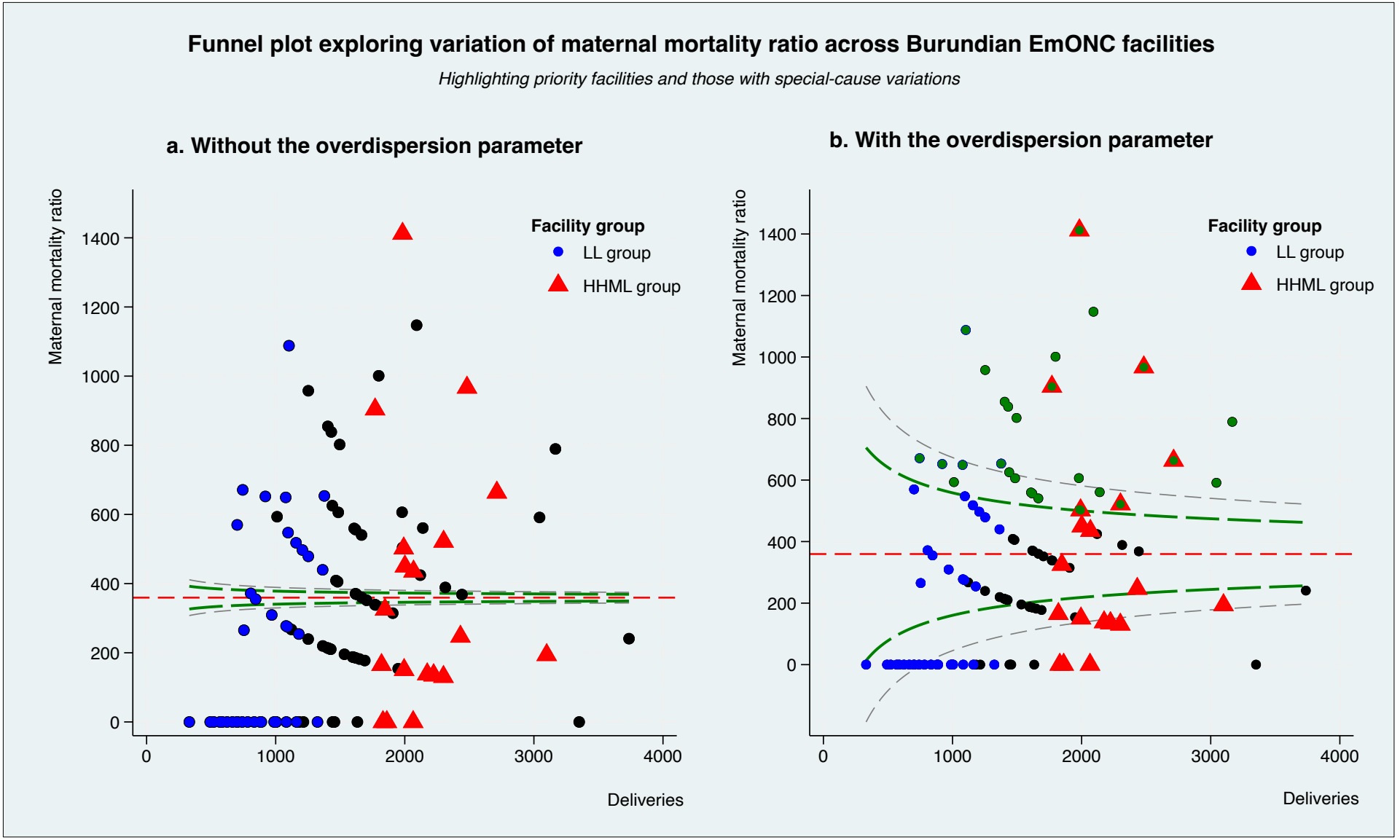


Figure 6.3 is the funnel plot comparing MMR variations across Burundian EmONC facilities with unadjusted control limits (Figure 3a) and adjusted control limits (Figure 3b). The horizontal dotted red line corresponds to the expected MMR, the bold dotted green lines correspond to the 95% (i.e., p-value 0.05 and 2 standard deviations) control limits, while the dotted grey lines encapsulate 99.8% (i.e., p-value 0.002 and 3 standard deviations) lower and upper limits. Generally, facilities inside these limits are "under control" while those outside them are not in control and warrant further investigation. Typically, as the outcome in MMR, fair interpretation would be that facilities below the lower limit (i.e., those with lower than expected MMR under normal circumstances) are "excellent" performers as recording fewer deaths and those above the upper limit are worrisome as they record higher MMR than expected under normal conditions. LL stands for low deliveries and low complications; HHML means high deliveries, high complications, and moderate or low delivery care professionals. The green dots on Figure 3.b indicate facilities warrant further investigation.

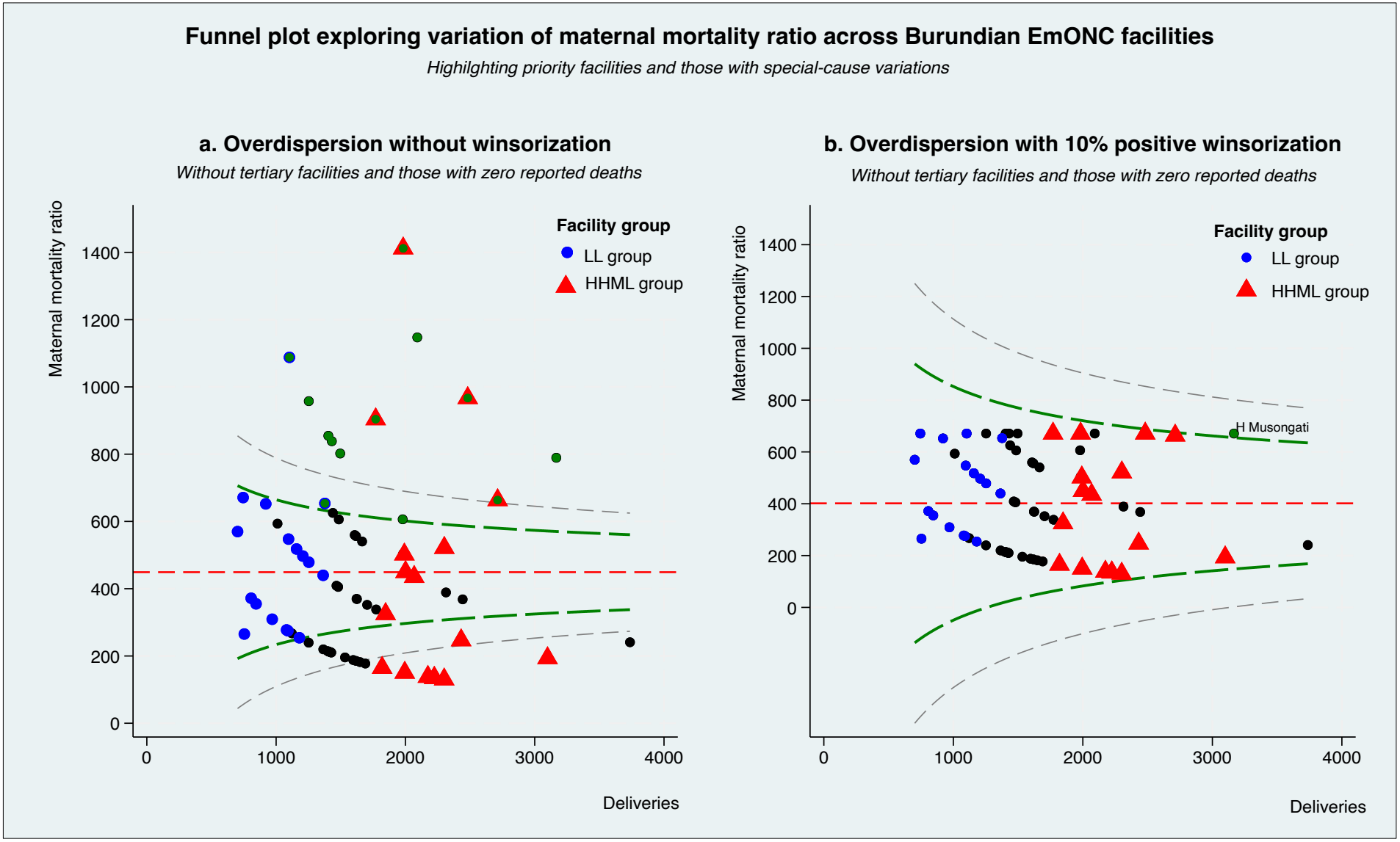


Figure 6.4 is the funnel plot comparing MMR variations across Burundian EmONC facilities without winsorization (Figure a) and with winsorization (Figure b). The horizontal dotted red line corresponds to the expected MMR, the bold dotted green lines correspond to the 95% (i.e., p-value 0.05 and 2 standard deviations) control limits, while the dotted grey lines encapsulate 99.8% (i.e., p-value 0.002 and 3 standard deviations) lower and upper limits. Generally, facilities inside these limits are "under control" while those outside them are not in control and warrant further investigation. Typically, as the outcome in MMR, fair interpretation would be that facilities below the lower limit are "excellent" performers (beyond expectation) and those above the upper limit are worrisome as they record higher MMR than expected under normal conditions. LL stands for low deliveries and low complications; HHML means high deliveries, high complications, and moderate or low delivery care professionals. The green dots indicate facilities warrant further investigation.

6.4.3. Identifying priority EmONC facilities

Results of the univariate facility categorisation in Table 6.1 show that facilities are correctly classified (i.e., reliability scores $\lambda > 0.7$) across low, moderate, and high categories with a relatively balanced distribution although the low category appears to be more prevalent. Next, I diagnosed using the bivariate criterion in Figure 6.5 three sets of facilities useful for policy attention; 28 facilities that perform large volumes of deliveries with high rates of maternal complications, 13 facilities handling high volumes of deliveries and with moderate numbers of complications, and 14 facilities manging moderate delivery volumes but with high numbers of complications.

	Low category n (%) facilities	**Moderate category** n (%) facilities	**High category** n (%) facilities	**Reliability score (λ)**
Deliveries	[331 – 1407] 48 (42.86)	[1408 – 1643] 23 (20.54)	[1644 – 3737] 41 (36.61)	> 0.91
Maternal complications	[22 – 383] 54 (48.21)	[384 – 496] 16 (14.29)	[497 – 1538] 42 (37.50)	> 0.91
Human resources	[0 – 2] 56 (50.00)	[3 – 4] 32 (28.57)	[5 – 18] 24 (21.43)	> 0.77

Table 6.1 summarises EmONC classification using the overdispersion z-score method. I define for each metric the benchmarking criteria in square brackets alongside the number and proportion of facilities falling into each category. Reliability scores $\lambda > 0.7$ indicate that facilities are correctly classified while chances of facility misclassification are almost eliminated as λ approaches 1.

Among the 28 facilities managing high volumes of deliveries and handling high prevalence of complications, a notable subset of 9 facilities that have low human resources and another 11 facilities with moderate staffing levels specifically warrant attention. In line with the conceptual framework depicted in Figure 6.1, these 20 facilities comprising 8 BEmONC and 12 CEmONC are identified as high priority based on their workload and resource constraints. Indeed, prioritising these facilities for workforce strengthening seems intuitive to ensure quality care and mitigate adverse outcomes in high-demand settings.

Furthermore, from the group of facilities experiencing high to moderate delivery volumes coupled with moderate to high complications, that is a set of 13 facilities with high or moderate deliveries and 14 facilities with moderate and high complications, I added the human resource criterion to identify a subgroup of four facilities which I

reason should also be considered as critical targets for a priority workforce investment. This group includes three BEmONC and one CEmONC facility, all characterised by low human resource capacity.

The above reasoning suggests a total 24 priority facilities might be identified, distributed across 15 of the 18 provinces of Burundi, with very significant disparities between their workloads and available human resources. These facilities perform nearly 30% of all deliveries taking place within the EmONC network and manage approximately 35% of obstetric complications. However, they are currently allocated only 15% (57 out of 374) of the total workforce in the EmONC system. Notably, 5 out of 12 priority CEmONC facilities lack a medical doctor and 13 out of these 24 priority facilities do not have a midwife.

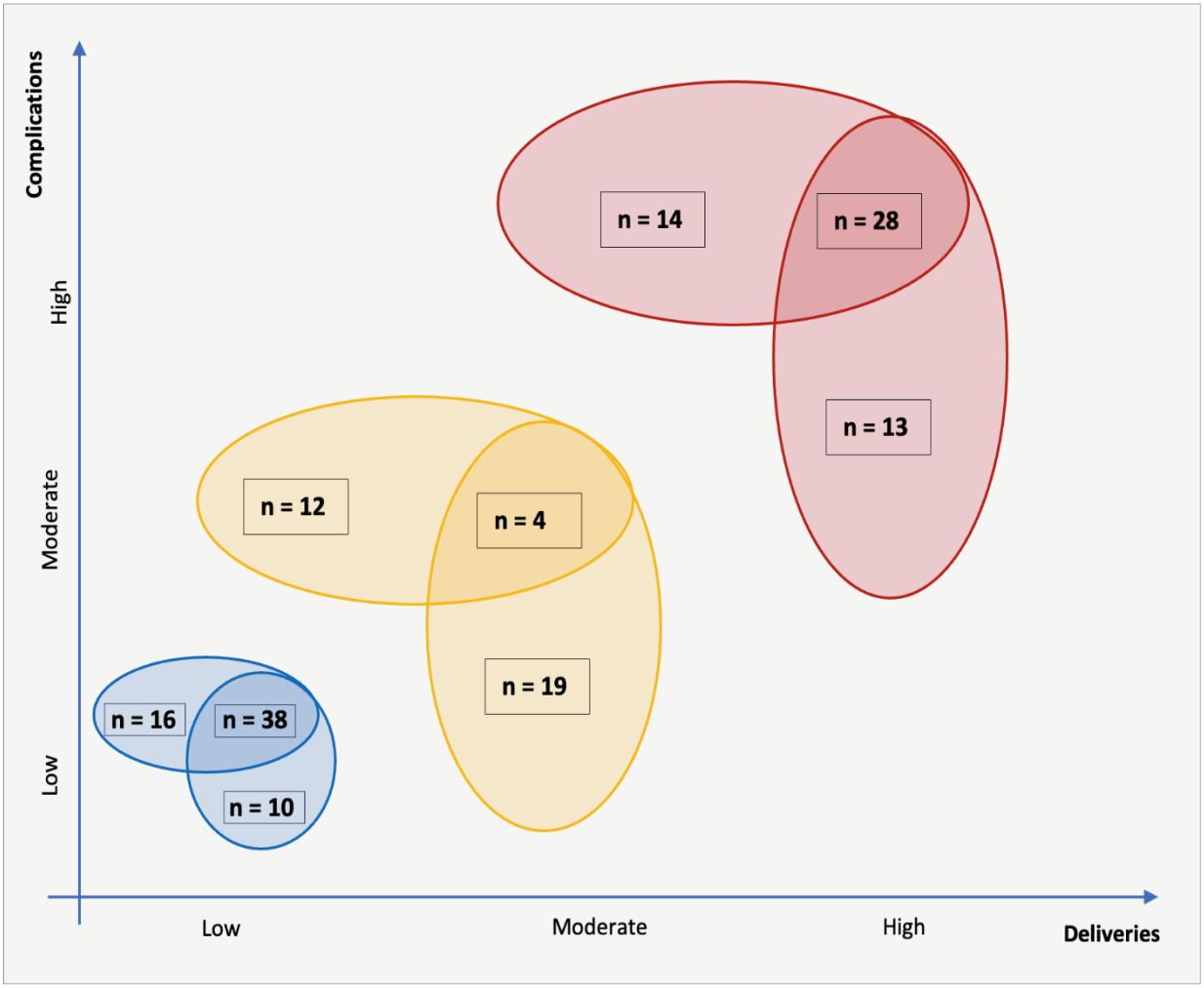


Figure 6.5 summarises the number of facilities using a combination of different levels of workloads. For instance, Table 6.1 indicates that 41 and 42 facilities belong to the high deliveries and high complications groups respectively using the overdispersion z-score method while Figure 6.5 which combines deliveries and complications shows that 28 of these two groups of facilities performed high levels of both deliveries and complications. Similar analyses were done using moderate and low levels of deliveries and complications.

6.5. Discussion

I demonstrate in this Chapter that the B/CEmONC designation used by the government in Burundi does not seem to match facilities' reported service volumes or case-mix. I went on to develop a framework that uses characteristics of EmONC facilities to highlight those that might be prioritised especially for workforce investment. Allocating resources where they are most needed may be strategically beneficial for Burundi because this low-income country may not immediately address identified needs requiring an investment that amounts to nearly US$33 million over 5 years to strengthen all the 112 designated EmONC facilities in line with its current policy norms.[318] In fact, even if the necessary budget was available, allocating investments based on Burundi's normative policy might well exacerbate equity gaps by strengthening facilities with lower workloads as much as those with very high service demand.

The first important and policy-relevant finding from this Chapter concerns the misclassification of facilities into B/CEmONC facilities. First, while international guidelines recommend linking 4 BEmONC to 1 CEmONC facilities per 500,000 population,[344] the Burundian EmONC network comprises 59 and 53 B/CEmONC facilities respectively; equating to 1.1 BEmONC facilities for each CEmONC facility and both per approximately 107,000 population. Second, workload analysis revealed that 11 BEmONC facilities are between 1.5 to 2 times busier than a set of 31 CEmONC facilities despite the CEmONC facilities generally (and by design) having capacity advantages.[318] In fact, I showed in Figure 6.2 and statistically that both facility types manage comparable proportions of maternal complications per deliveries indirectly indicating serious issues with the referral system. Additionally, although BEmONC facilities are by design not permitted to perform caesarean sections or blood transfusion,[41,344] I found a medical doctor who offers these services in 3 BEmONC facilities. Conversely, 22 CEmONC facilities lack a dedicated doctor and cannot thus perform caesarean section.[318]

Based on the misalignment in facility categorisation, one sensible option would be reviewing and limiting the number of designated EmONC facilities to strategically deploy and focus scarce resources where they are most needed. In fact, beyond

Burundi, studies show that EmONC maternities in LMICs struggle to offer quality care partly because countries form ambitiously large networks of facilities that are difficult to sustain and keep fully operational.[345-348] However, I showed in this Chapter that annual maternal mortality data in the context of Burundi's EmONC facilities is unsuitable for prioritising facilities primarily because the small population size served by each facility (i.e., approximately 107,000 inhabitants are served by 1 BEmONC and 1 CEmONC) makes mortality rates highly unstable. The latter instability arises from the fact that, with fewer cases, even one maternal death can significantly distort a reported annual mortality rate thus leading to highly overdispersed data that do not reliably reflect true performance or risk levels. Another possible explanation for this is that EmONC facility staff may underreport maternal deaths to boost financial incentives awarded to performing facilities (i.e., under the PBF scheme).[349,350] This possibility is supported by identifying 31 EmONC facilities that reported zero maternal deaths over a period of 12 months including busier facilities delivering up to 3351 women and that collectively report dealing with more than 55% of delivery complications.

My proposed prioritization framework therefore focuses on 24 facilities comprising 11 BEmONC and 13 CEmONC facilities that are severely understaffed but report high volumes of deliveries and complications. These facilities perform about one third of deliveries and manage 35% of complications although they have less than 15% of the total EmONC network workforce.

Finally, analyses performed in this Chapter have two major limitations. First, excluding mortality from the framework implies that my approach to facility categorisation could result in resource allocation to facilities where mortality is not the highest. This would reduce allocative efficiency and the overall impact. Secondly, I was unable to include neonatal outcomes in my analyses as accurate records were generally lacking for stillbirths and neonatal mortality. Thus, I relied on maternal records as a proxy indicator of both maternal and neonatal health under the hypothesis that strengthening facilities to improve quality maternal care would translate into better neonatal health outcomes.[351,352] A further limitation is that my focus on resource allocation was limited to health workers, and without controlling for clinical case-mix which might have affected outcomes, despite there being wider prevailing non-human capacity deficits[318] but I have identified and costed these needs in Chapter 4 and further provided the

foundations for focusing on workforce in the Section 1.7 of the Introductory Chapter. Additionally, my prioritisation framework did not account for equity in facility access, therefore focusing investment on a subset of facilities could potentially exacerbate existing disparities and widen inequities in access to maternal and neonatal care.

6.6. Conclusion

This Chapter demonstrated that the current Burundian policy on B/CEmONC facility categorization is misleading in practice with some BEmONC facilities often managing higher volumes of normal and complicated deliveries than CEmONC facilities although the latter are relatively better resourced. I proposed an empirical framework that helps to categorise facilities using prevailing workloads and human resources demonstrating how it could identify facilities that are a priority for investment in the context of highly constrained resources. Accurate and long-term mortality data if available could further inform prioritisation of investments as could more accurate information on needed non-human resources. These analyses could be further developed through subsequent economic and budget impact evaluations to better inform policymakers of both the likely costs and expected benefits from strengthening priority or all EmONC facilities. These analyses would also benefit from considering the effects on equity of targeted investments.

Overall, the analysis performed in this Chapter uncovered significant discrepancies in facility classification, workload distribution, and maternal mortality data which are further compounded by potential underreporting of deaths or overreporting of workloads to enhance performance-based incentives. Focusing on a target subset of 24 high-volume, understaffed facilities that handle a substantial proportion of deliveries and complications offers a more reasonable and impactful approach though it raises concerns about potentially widening inequities in facility access. Ultimately, findings from this Chapter advocate for a more nuanced, data-driven strategy for resource allocation within Burundi's EmONC network, an approach that prioritises facilities based on actual service demand and specific contextual factors rather than relying solely on normative designations. Such an approach would promote more efficient use of limited resources and could potentially lead to improved maternal and neonatal health outcomes.

CHAPTER 7.
EXAMINING THE IMPACT OF WORKFORCE INVESTMENTS

This Chapter contains some of the content of a manuscript that will be submitted to either the Cambridge Journal of Benefit Cost Analysis or the BMJ Cost Effectiveness analysis journal. (Manuscript Title: A decision-tree model to evaluate the impacts of workforce investments aimed at strengthening Emergency Obstetric and Neonatal care (EmONC) facilities in Burundi). This manuscript is provided as Appendix 6.

I began this research by exploring, quantifying, and costing EmONC resource deficits based on Burundian norms and recommendations from MNH experts. At this stage, Burundian health policymakers recognised the existing capacity deficits in EmONC resources and realised the likely budgets necessary to address these gaps without however accounting for current workloads or mortality rates. However, investments aimed at closing capacity gaps without paying attention to workload and, if data permits, mortality variability may fail to optimise resource allocation and could exacerbate existing inequities.

Then, I examined the EmONC competencies of delivery care providers with an aim to identify the need for targeted skill-building training. EmONC training has a significant influence on investments aimed at enhancing EmONC facility readiness to provide quality-adjusted care. Next, I focused on human resources seeking to identify priority facilities where Burundi would focus investment in the face of limited budget capacity. However, policymakers need to understand the potential impact of any investment. Therefore, this Chapter aims to estimate the effects of EmONC workforce investment using decision-tree modelling as highlighted in Section 2.6 of the literature review chapter. The Chapter begins with Box 7.1 highlighting key results and continues with the background, methods, results, discussion, and conclusion.

Box 7.1 Key findings from Chapter 7

Existing knowledge

- Persistent poor resource allocation is a key factor driving inefficiencies in healthcare systems in 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.

Methods

- I 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, I 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 the 24 priority facilities identified in Chapter 6. A decision tree model helped to predict the costs per maternal death averted.

Key findings

- Findings revealed that workforce gaps across Burundian EmONC facilities are variable, pointing to severe health worker shortages and maldistributions. 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. If Burundi faces budget constraints, this country 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 option is more cost-effective with an expected expenditure of US$ 2,380.58 for each maternal life saved, nearly half the cost of the alternative, full packages.

Policy and practice implications

- Results indicate that a partial investment of two additional midwives in each EmONC facility facing human resources deficits is more cost-effective than implementing comprehensive midwifery packages, though many practical considerations must be carefully evaluated during policy formulation. Nonetheless, the study suggested that targeted, partial but sufficient workforce investments combined with efforts to address physical and infrastructural challenges could be the most cost-effective, feasible, and impactful strategy to improve maternal health outcomes in Burundi.

7.1. Introduction

The Burundian EmONC network faces significant capacity challenges that hinder the delivery of quality maternal and newborn care. Previous estimates in Chapter 4 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.[318] I estimated that an amount of US$ 32.9 million would be required to address these deficits from 2025 until 2030.[318] Therefore, if Burundian policymakers are to fulfil their pledge of achieving the 60% and 50% reductions in maternal and newborn mortality rates by 2030,[333,353] they must make appropriate maternal health investments and where possible tackle inefficiencies within the EmONC healthcare system.

However, the total Burundian health budget amounting to Burundian francs (BIF) 2,228.7 billion (approximately US$ 112.4 million), which constitutes 9.6% of the total government budget[157] results in a health expenditure of only BIF 25,512 (about US$ 9) per capita. In such a context, policymakers may struggle to mobilise the US$ 32.9 million necessary to strengthen the EmONC network in line with Burundi's own material and human resource norms. This challenge is compounded by the country's competing development priorities, persistent health burdens and outbreaks that persistently overwhelm the already fragile health system.[158-162]

Indeed, Burundi has engaged in numerous strategic planning and resource allocation discussions in healthcare over the past two decades, driven by rising priorities and the budgetary pressures, but these efforts have been undermined by an overall economic downturn.[11,163,164] To achieve the goal of ending preventable maternal mortality (EPMM)[165] and advancing health equity[166,167] will require Burundian policymakers to demonstrate a bold political commitment to health reforms and the strategic redirection of limited resources; commitment that is mostly lacking in many LMICs.[168,169] 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.[170]

To assist Burundian health policymakers in prioritising EmONC investments, I developed in collaboration with stakeholders four workforce investment scenarios and estimated their likely costs and potential maternal health benefits over the 2025–2030 horizon. Specifically, I 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 might save. Findings from this Chapter aim to inform policy discussions involving key stakeholders and development partners including UNFPA, WHO, JICA, Pathfinder, and various local research and service delivery institutions that support the Burundian maternal health programme.[51]

7.2. Methods

7.2.1. Agreeing EmONC workforce policy investment proposals

I developed four scenarios for EmONC workforce investment, as summarised in Table 7.1, which were discussed and validated with study stakeholders (see Supplemental material 2). The first or status quo scenario considers that Burundi may not prioritise any EmONC workforce investments in the near term. The second posits that 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 adding two midwives in each EmONC facility (a typical policy option) or concentrating resources on 11 BEmONC and 13 CEmONC priority facilities that would receive a comprehensive package of necessary human resources. These 24 priority facilities were identified in Chapter 6 based on their high delivery workloads, high prevalence of maternal complications, and high levels of shortage of human resources relative to reported workloads.

Scenarios	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 7.1 Workforce investment scenarios to strengthen Burundian EmONC facilities. These alternatives were developed with input from study stakeholders (see Supplemental material 2). 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 WISN method.

7.2.2. Choice of economic model: the decision tree model

The objective of this Chapter was to provide Burundian decision-makers with insights into the various cost and benefit implications associated with the four EmONC workforce investment scenarios developed with stakeholders (see Table 7.1). This analysis was conducted using a decision tree model which facilitates the prediction and comparison of costs and impacts related to various investment decisions (I have provided a detailed explanation and justification for this model choice in Section 2.6 of Chapter 2).[236,354] Therefore, my 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.[236] 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 QoC thereby reducing mortality rates.[355,356] Under this assumption, the likelihood of labouring women developing and succumbing to obstetric complications would decrease with the addition of skilled delivery personnel, particularly in contexts

characterised by significant workforce shortages. However, this effect is expected to plateau and follow the law of diminishing returns as investments increase.[357-359]

7.2.3. 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, I analysed maternal and neonatal care records from each of these facilities, 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.[279,360-364]

The above records were used to estimate the prevailing yearly workloads in minutes using the activity duration approach outlined in the WISN methodology.[209] To obtain the activity duration estimates (in minutes) of various maternal and newborn care tasks, I summarised the literature based on studies employing the WISN approach, including a multicounty study conducted in 12 African countries[365] as well as individual studies conducted in Burkina Faso,[366] Côte d'Ivoire, Niger, and Kenya,[367] Brazil,[368] and Iran.[369] 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 if needed. Additional activities reported in Burundian EmONC facilities include care following incomplete abortions, which I estimated 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. Detailed activity durations are summarised in Table 7.2.

The goal was to compare workloads with available workforce capacity in order to derive staffing deficits. To achieve this, I 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 of Box 7.2). I then estimated the workforce capacity by determining the total number of minutes each skilled delivery care 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, I factored other possible reasons of absenteeism as explained in Equation 2 of Box 7.2 and based on existing evidence assuming that approximately 15% of daily working time is allocated for authorised breaks (e.g., lunch) and personal and social matters (e.g., social communications), as well as possible administrative tasks, fatigue-related inactivity, and delays at work.[369] Consequently, a typical health worker in Burundi is expected to formally work 80,784 minutes in a year. Detailed algebras are provided in Box 7.2.

Next, based on the expected time it would take to provide care to the numbers and case-mix of women attending a facility I subtracted the working time available at a facility, based on its workforce complement. The difference corresponds to the required working time deficit which is a measure of 'overwork' at facility level. If this difference is negative, the available capacity surpasses the required number of staff. Else, a positive difference implies a deficit while a null difference represents a perfect match between the needed and available staff capacity. Finally, the estimated working time deficit (in minutes) in each facility was used to calculate its additional workforce requirement by back-translating this time deficit into human resources.

Publication	Delivery care Professional	Type of activity (care)	Activity duration (min)
De Menezes et al., 2022 (Brazil)[368]	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)[369]	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)[366]	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)[367]	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)[367]	Nurses and Midwives	Delivery care	242
		Postnatal care	28
		Family planning consultation	24
Kunjumen et al., 2022 (Kenya)[367]	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)[365]	Midwives	Admission of pregnant woman	40
		Postnatal care	31
		Normal delivery	196

Table 7.2 summarises the findings from a literature search on the standards and durations of maternal and newborn care activities, focusing on published research in LMICs particularly within the African context. The 14 African countries on which these estimates are drawn include Benin, Botswana, Burkina Faso, Chad, Cote d'Ivoire, Ghana, Kenya, Liberia, Malawi, Namibia, Niger, Nigeria, South Africa, and Zimbabwe.

Box 7.2 Equations and assumptions used to estimate workloads and workforce capacity

$$\lambda_j = \sum_{i=\mathrm{n}} \mathrm{X}_{ij} \times \delta_i$$

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 Table 7.2). 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. $\alpha = 0.85$ where 15% corresponds to the time discount rate 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:

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

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:

$$\textbf{\textit{Capacity}} \;=\; 7\ \textit{providers} \times 198\ \textit{days} \times 8\ \textit{hours} \times 60\ \textit{minutes} \times 0.85$$

In the context of Burundi I 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.

7.2.4. Pathway outcomes and their probabilities

The ultimate outcomes in my decision pathways are either maternal death or survival. To estimate these outcomes, I 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).

I 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.[232] Previously in 2015, a similar study conducted across 58 LMICs indicated that 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.[231] Using the above sources, I calculated the average predicted impact of comprehensive midwifery staffing by averaging the two reported reductions (i.e., 14.0 and 21.33% reductions), thus applying an estimated 17.67% reduction in MMR. For sensitivity analysis, I used these reported reductions individually, applying a range from 14.0% to 21.33% reductions in MMR to account for variability in the estimates. 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 7.3 and Figure 7.2, 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 7.4 and fully detailed in the Supplemental material 14. First, I applied the WISN methodology[209] to estimate the required activity time in minutes based on workloads and the available capacity which I derived from current staffing levels. This allowed me 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 7.2). 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., see the first line of Table 7.4), adding two midwives would reduce the workforce gap deficit by 12.53%. Next, I 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 7.4 and in the Supplemental material 14, the MMR reduction increases with the size of the workforce gap addressed, capping this at 17.67% if the addition of two midwives fully addresses the prevailing deficit (i.e., if the workforce gap covered equals to 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[231-233]
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 7.3 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*	HRH 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
.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.
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 7.4 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 7.1). 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 full table of estimates is provided as Supplemental material 14.

7.2.5. 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 Chapter 3 and Chapter 4 and in our previous report.[318] This includes government salaries adjusted for an annual 3% growth rate and the costs associated with the recommended onset and biennial EmONC training. For better interpretation, health outcomes (i.e., maternal deaths) were calculated by multiplying pathway probabilities by 100,000 deliveries to meet the MMR standard definition. Additionally, for each investment option relative to the status quo I estimated the expected number of maternal lives saved per 100,000 deliveries which allowed me to compute the cost per maternal life saved. To address uncertainties in the parameters and assess the robustness of our estimates, I conducted a sensitivity analysis using the upper and lower limits of the impact of each midwifery intervention option on maternal mortality, see Section 7.2.3 for details.

7.3. Results

7.3.1. Human resources needs and budgetary implications

For brevity, I used midwives as the proxy delivery care staff to estimate the workforce needs and the corresponding budget and benefit implications. Subsequently, Figure 7.1 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. Explorations revealed that only 7 hospitals out of 111 EmONC facilities meet the workload staffing index based on the WISN criteria. Among these 7 hospitals, five are tertiary hospitals located in Bujumbura capital city and have between 1 to 6 more delivery care professionals than required with a total of 20 excess health workers (see Table 7.3). Conversely, Figure 7.1 and Table 7.3 together prove 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. Furthermore, as illustrated in Figure 7.1, the addition of two midwives to each facility would fully address the workforce deficit in only four additional facilities.

Using the WISN approach, I estimated a total workforce deficit across the EmONC network of 58,649,184 minutes equivalent to approximately 726 skilled delivery care providers (back-converted using details provided in Box 7.2), which I expressed in midwives. Investment scenario 2 involves fully addressing the estimated workforce gap in 104 facilities with shortages, excluding those with sufficient workforce. I found that this option would require approximately BIF 32,494,340,294.22 (equivalent to US$ 11,092,717.23) to cover salaries and provide these additional staff with biennial EmONC training over a period of five years. Option 3, adding 2 nurses to all facilities with a deficit would incur an estimated cost of approximately BIF 9,309,673,252.34 (US$ 3,178.078.77) for salaries and training for 208 newly recruited midwives over five years. In the targeted approach, a workforce deficit of 17,287,776 minutes within the 24 priority facilities was present which translates to 214 midwives necessitating an estimated budget of BIF 9,578,221,519.23 (US$ 3,269,754.11) for salaries and training over five years.

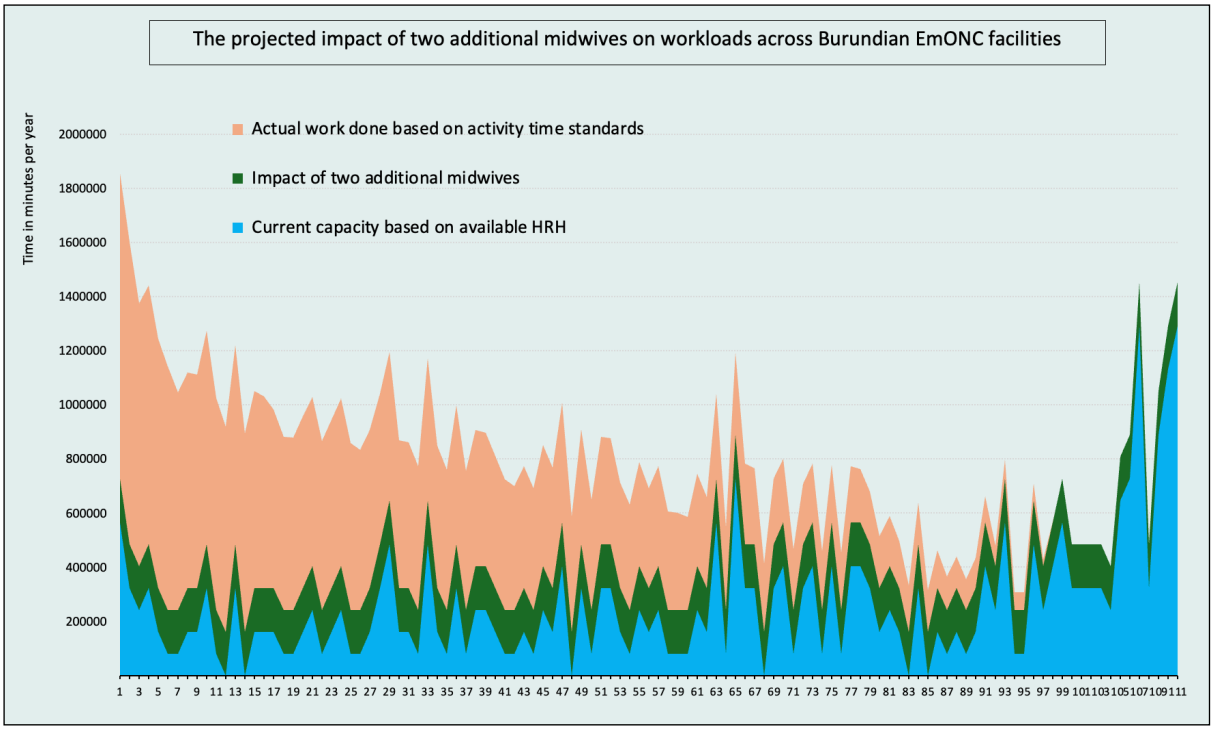


Figure 7.1. Workforce deficits by facility. This figure compares the current workforce capacity in minutes against prevailing workloads to highlight workforce gaps in each facility. Additionally, it illustrates the potential impact of two additional midwives on narrowing these existing workforce deficits.

7.3.2. Predicted maternal health gains

Under current circumstances, the status quo branch in Figure 7.2 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, my analyses anticipate approximately 3,208 maternal deaths among the estimated 170,819 deliveries to occur annually across the 112 EmONC facilities. If more deliveries take place in these EmONC facilities as generally expected due to the increasing birth rate, the number of maternal deaths is expected to increase proportionally.

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 details in Table 7.2). We see in Figure 7.2 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, the first policy scenario considers 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%) (see Table 7.3), 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 priority facilities performed 49,134 deliveries in 2021, representing nearly one third 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) as shown in Table 7.5.

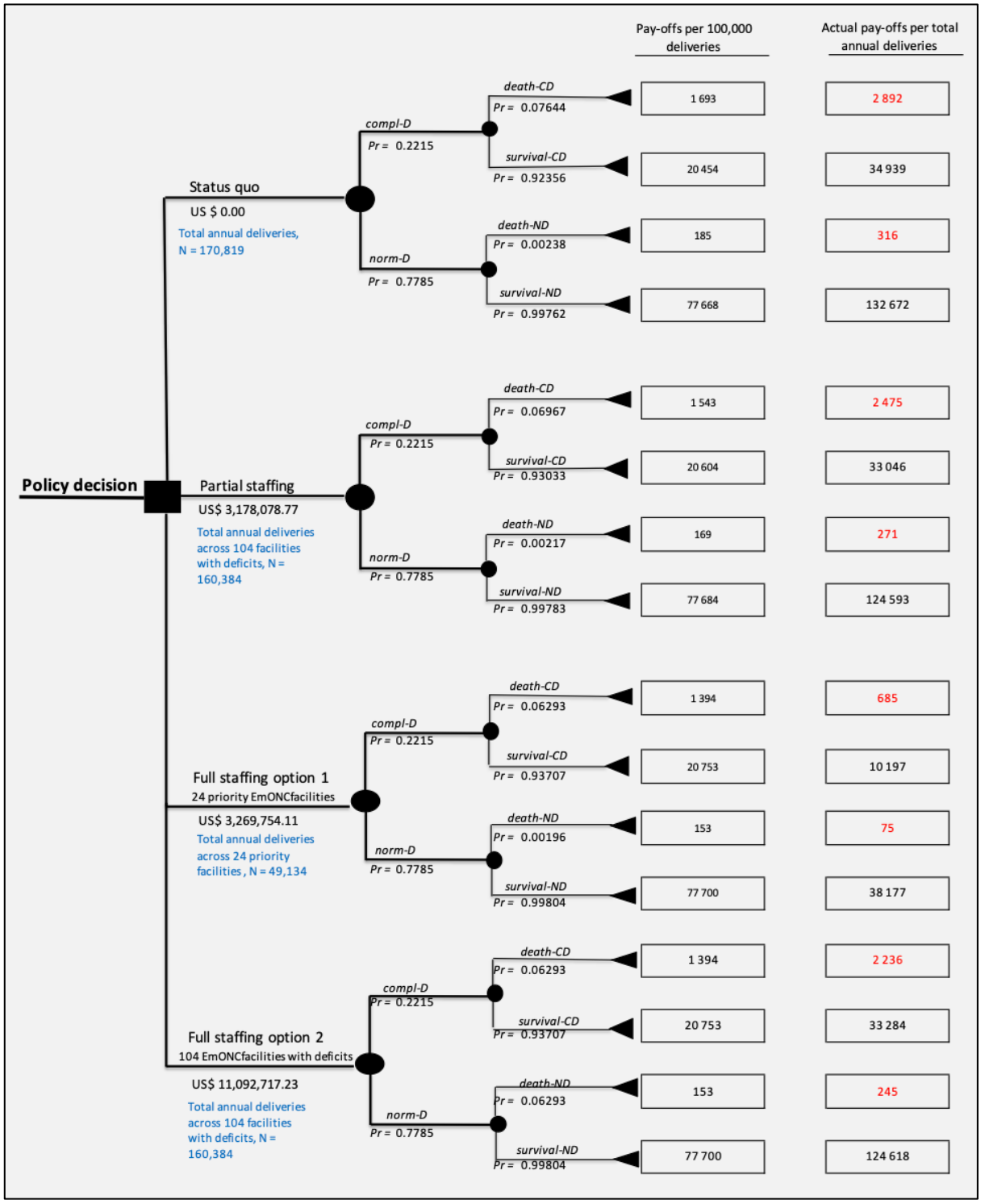


Figure 7.2. Decision Tree predicting the outcomes of different EmONC investment options. This decision tree features three branches each representing an investment decision with the full staffing branch representing both an investment targeting the 24 priority facilities and the 104 EmONC facilities. 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-effectiveness analysis are summarised in Table 7.5. First, I annualised the budgets (in US dollars) of all investment alternatives by dividing each total investment by five years. In the face of no investment, it is estimated that 3,012 out of 160,384 labouring mothers will die annually. In comparison, a partial investment of two additional midwives in each of the 104 facilities is likely more cost effective with an average expenditure of US$ 2,380.58 (between US$ 1,973.96 and US$ 3,012.40) spent for each maternal death averted while implementing any of the full workforce packages would be significantly more expensive; costing nearly double the amount required to save one maternal life. 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 a full workforce package is provided across the 104 facilities. If this 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). We further see in Table 7.5 that none of the investment scenarios is expected to reduce MMR below 1,400 maternal deaths per 100,000 livebirths.

	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 7.5 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.

7.4. Discussion

This Chapter employed decision tree methodologies to predict the costs and benefits associated with four workforce investment scenarios targeting Burundian EmONC facilities. The primary objective of this study was to assist Burundian health policymakers in prioritising EmONC investments amidst limited resources and competing health priorities.[158-162,370-373] 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 if the government is to adhere to its stated norms, representing an annual increase of roughly 6% in the total health budget.[318]

The first investment scenario posits that Burundi does not prioritise any EmONC investment. The second assumes budget availability and suggests a comprehensive investment to fully address workforce deficits across all EmONC facilities with such a need. 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 their high delivery workloads, high prevalence of maternal complications, and fewer 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, the WISN criteria revealed 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 the identified workforce deficit, an estimated 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, adding two midwives in each of 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). A comparison of these alternative investment options shows that the partial scenario; consisting of two additional midwives; is more cost-effective. It is projected to save one maternal life at an average cost of US$ 2,380.58 (sensitivity range between US$ 1,973.96 and US$ 3,012.40) whereas any of the two full package interventions would incur nearly double this cost per each maternal life saved.

Burundi, like many LMICs, does not have an explicit cost-effectiveness threshold (CET) or a willingness-to-pay threshold for a maternal life-year saved.[374] Nevertheless, the literature proves that country-specific CETs can be approximated using per capita GDP.[374-378] For LMICs, these thresholds commonly range from 1 to 3 times per capita GDP per health outcome unit, often expressed as quality-adjusted life-years (QALYs).[376] Using Burundi's per capita GDP in 2024 (i.e., US$ 153.93)[379] gives an indicative range of US$ 153.93 to US$ 461.79 per one-year maternal life gained. Further, the WHO Choosing Interventions that are Cost-Effective (CHOICE) guideline does not prescribe a single universal threshold for a maternal life saved. Instead, it promotes using context-appropriate benchmarks and emphasises that thresholds should reflect country opportunity costs, budget impact, and equity considerations.[376] Where possible, thresholds should be derived from methods that estimate opportunity costs (e.g., value of a statistical life, VSL) and empirical studies, and it is recommended to report a range of CETs rather than a single point estimate.[374-378] A large scale study estimating CETs for 174 countries by income level found that, for low-income countries (LICs), CETs range between US$ 87 and US$ 320 (median: US$ 163) per QALY gained or from US$ 78 to US$ 274 (median: US$ 150) per life-year saved.[380]

Taken together, these sources suggest that Burundi's CET would likely fall roughly between US$ 78 and US$ 461.79 per life-year or QALY gained. Given that the most cost-effective investment option in my thesis costs US$ 2,380.58 per maternal life saved, and assuming a woman's remaining expected lifetime is between 20 and 30 years (based on Burundi's life expectancy of 65 years),[381] the implied cost per maternal life-year saved ranges from approximately US$ 79 (i.e., US$ 2,380.58/30 years) and US$ 119 (i.e., US$ 2,380.58/20 years). Both these bounds fall within the cited CET range. Even when applying the per capita GDP-based thresholds, the full workforce package; the most expensive scenario; would cost about US$ 210 per maternal life-year gained and thus would lie within Burundi's CET range.

However, the above evidence which is intended to inform EmONC policy should be interpreted with caution. First, the proposed partial investment of adding two midwives in each facility would only fully address gaps in four additional facilities, leaving over 100 facilities with varying levels of HRH deficits. In many of these, staffing shortages would remain severe enough to hinder effective teamwork and the organisation of continuous shifts (i.e., three shifts per day) thereby impeding quality care. Indeed, the management of maternal complications requires coordinated interprofessional teamwork involving two or more healthcare professionals with complementary skills who exert concerted physical and mental effort in providing care.[382-384] Unfortunately, in facilities with only one or two existing workers, the addition of two midwives would still be insufficient to facilitate effective teamwork or sustain regular shifts.

Second, since 22 CEmONC facilities lack a medical doctor, the addition of two midwives does not enable these hospitals to provide advanced interventions such as caesarean sections and blood transfusions which are essential for comprehensive care. Third, the estimated impact of midwifery interventions on MMR was derived from modelling studies that used the LiST methodology across multiple LMICs and its applicability to Burundi remains uncertain. MMR reductions are likely more significant where baseline mortality ratios are highest. In Burundi where facility-based MMR exceeds 1,800 maternal deaths per 100,000 deliveries based on the 2021 facility records, the projected 17.67% reduction (from 14% to 21.33%) may not accurately reflect the true impact. Additionally, my analyses may have relied on inaccurate data with maternal deaths

possibly being underreported and workloads inflated or fabricated to enhance financial performance-based incentives as I suggested in the previous Chapter.

These possible limitations of my approach include the fact that none of the proposed investment options are expected to reduce the MMR below 1,400 maternal deaths per 100,000 deliveries (see Table 7.3), an extremely high figure even for referral facilities. For comparison, in Somaliland where the population-based MMR exceeds 750 per 100,000 deliveries (i.e., nearly twice that of Burundi), a study conducted in a major referral hospital reported a facility-based MMR of 462 per 100,000 livebirths (95% Confidence Interval, CI: 310–670).[385] EmONC facility-based MMR was similarly high in a Ugandan referral hospital (i.e., 1729 maternal deaths per 100,000 deliveries)[386] but much lower (i.e., around 150 maternal deaths per 100,000 deliveries) in Kenya,[387] in Malawi,[388] and across many sub-Saharan African countries.[389-392]

Another concern is the implications of failing to capture the economic consequences associated with maternal and neonatal morbidity (see Section 7.2.4). Indeed, while in my model the outcome is death or survival, maternal morbidity imposes substantial direct medical costs, productivity losses, caregiver burdens, and long-term disabilities that affect families and the broader economy. Thus, omitting these costs can bias cost-effectiveness towards focusing on mortality alone, underestimating the true societal value of interventions that further prevent morbidity and risking to limit investments in interventions that reduce morbidity. Incorporating morbidity costs yields a more comprehensive assessment of the true value in economic evaluation studies.[393,394]

Furthermore, it is worth remembering that EmONC facilities constitute less than 8% of all health facilities nationwide and perform only one third of the 85% of deliveries that occur in health facilities,[34] even though they manage nearly two-thirds of obstetric complications.[50,51] However, an estimated 1,878 mothers die per 100,000 deliveries within these specialised maternity hubs despite the fact that they have gained policy attention over the past eight years. Given this context, it is likely that mortality rates are even higher in non-EmONC facilities largely due to referral challenges and the expected heightened limited resource capacity in the latter non-EmONC facilities. In fact, the substantial capacity deficits identified across EmONC facilities in Chapter 4 could suggest that facilities providing delivery care that are not designated as EmONC

facilities may also face pronounced structural challenges and capacity issues which hinder the delivery of quality maternal and neonatal care. Numerous studies have consistently demonstrated that maternal mortality attributable to obstetric complications is significantly elevated in under-resourced health settings.[348,395-398]

These investment options will be discussed with stakeholders in Burundi in a priority setting workshop, focusing on the likely available or mobilizable health budget for immediate investment. Even though the partial investment is empirically more cost-effective, we will explore the practical implications of two additional midwives in each facility to ensure that any workforce investment made can enable teamwork across shifts. If Burundi is able to mobilise substantial funding for EmONC, we will explore how any supplementary budget could be strategically allocated to improve the overall facility environment by addressing previously identified non-staff related, physical issues.[318] Finally, if the maternity records used in this analysis are inaccurate, such discrepancies could compromise the estimation of workforce deficits potentially leading to misallocation of resources and diverting them away from areas of greatest need.

7.5. Conclusion

We have demonstrated the potential costs and benefits associated with partial and comprehensive EmONC network workforce investment scenarios within the context of Burundi. Although the parameters used in this modelling study are based on global empirical evidence and not specifically tailored to Burundi along with several limitations discussed in the previous section, we believe these findings remain relevant and can inform Burundian health policymakers in prioritising EmONC workforce investments. The decision-tree model implemented in this Chapter can be updated and applied regularly using routine EmONC monitoring data to inform planning, budgeting, and resources allocation. For instance, by integrating ongoing EmONC indicators such as facility readiness (available resources), service consumption (demand), treatment coverage, and health outcomes (mortality), the model can produce real-time feedback on bottlenecks, quantify the impact of different interventions to support adaptive decision-making at district and national levels. The results indicate that a partial investment of two additional midwives in each EmONC facility facing human resources deficits may be more cost-effective than implementing comprehensive midwifery

packages, though many practical considerations such as to how this would ensure teamwork across daily shifts must be carefully evaluated during policy formulation. Nonetheless, results of this Chapter suggested that targeted, partial but sufficient (i.e., to enable teamwork across shifts) workforce investments combined with efforts to address physical and infrastructural challenges could be a reasonable, feasible and impactful strategy to improve maternal health outcomes in Burundi.

Chapter 8. Discussion

The aim of my studies was to examine the capacity challenges within the Burundian EmONC network with a particular focus on human resources. The prime goal was to estimate capacity deficits and their corresponding budgetary requirements and to develop together with stakeholders alternative workforce investment options. Ultimately, this research seeks to assist Burundian health policymakers and stakeholders involved in the MNH programme in understanding the current challenges that undermine the attainment of MNH pledges in the face of continued high maternal and newborn mortality rates despite prior political and financial commitments. Furthermore, this study aims to inform future investment efforts by producing empirical evidence that illustrates how better information on inputs, service delivery (outputs) and outcomes may be used to identify (high) priority facilities for targeted investment in a situation of very constrained resources and the likely costs and benefits of alternative investment proposals.

In this Discussion Chapter, I explore the significance and relevance of the study findings. Specifically, I review, explain, and evaluate the results presented in Chapters 4 through 7 illustrating how they relate to existing literature on EmONC and the broader political context, further making an argument in support of my overall conclusions.

I begin the Chapter with a summary of major findings demonstrating how they collectively form a coherent body of information that can begin to inform policy decisions for Burundian health policymakers and MNH stakeholders. I develop specific sections to delineate the implications of the findings for the routine EmONC practice in Burundi such as the routine, termly EmONC monitoring which involves collecting maternal and newborn care records across all facilities four times a year and the biennial EmONC training targeted at all delivery care professionals. I also consider the need to re-examine the current Burundian EmONC policy to align with global standards and actual facility workloads. Finally, I reflect on how my experience conducting this study particularly the tools and methodologies I developed can be valuable for future assessments of the EmONC network.

The Chapter concludes with a section that highlights the strengths and limitations of my work, the recommendations for future policy directions, along with insights into my postdoctoral research perspectives and career development plans.

8.1. Major findings and their interpretation

At the beginning of this study (see results Chapter 4), my goal was to examine the capacity challenges of EmONC facilities in Burundi, focusing on human and non-human resources that are essential for safer childbirth and effective management of obstetric and neonatal complications based on the standards explicitly stated in the current Burundian EmONC policy. However, a thorough review revealed that this policy proposes resource levels that are suboptimal and insufficient to promote the provision of quality care. Regarding human resources for instance, while FIGO recommends a minimum of nine delivery care professionals in BEmONC facilities serving approximately 1,000 deliveries annually and 21 of these professionals in CEmONC facilities performing 3,000 deliveries per year,[249] the Burundian EmONC policy suggests only three and 14 professionals in BEmONC and CEmONC facilities respectively, regardless of the prevailing workloads.

This disconnect between local standards and global evidence prompted me to critically challenge the existing, local standards which I supplemented with MNH expert suggestions gathered through a rapid target survey. I combined the normative and expert suggested thresholds into three EmONC capacity benchmarks; a normative benchmark along with minimum and maximum benchmarks based on Burundian expert suggestions (details are provided in Table 4.2).

These three EmONC resource benchmarks were validated together with stakeholders and MNH experts (see Supplemental material 2). They propose different sets of EmONC resources with the maximum proposal offering a promising level of resources necessary for delivering quality care. I examined the availability and functionality of each resource against each of the three benchmarks. This process enabled me to identify capacity deficits at facility, district, and provincial levels and to estimate the

associated budgetary implications from a government perspective over a five-year strategic plan. I also briefly explored the relationships between resources and workloads at facility level.

Although my three benchmarks (i.e., normative and expect suggested thresholds) remained somewhat suboptimal when compared to current workloads, the findings underscored widespread and severe shortages of key resources and revealed an apparent lack of correlation between resource availability and workloads. For instance, I found that 95% of BEmONC and all CEmONC facilities lack the minimum human resources (i.e., assessed against the lowest benchmark) while 90% of all EmONC facilities require additional major equipment and physical infrastructure. Specifically, the most critical deficits across the network, as per the highest benchmark, amounted to 162 medical doctors, 1,005 midwives and nurses, 132 delivery rooms, 191 delivery tables, 678 and 156 maternity and newborn care beds, and 395 incubators, amongst others. These gaps translate into an estimated additional budget of US$ 32.9 million over five years (e.g., from 2026 until 2030), representing approximately 5.96% annual increase in the total health budget.

Detailed resource deficits and budget requirements associated with each benchmark scenario are provided in Table 4.4 and Table 4.5. These results offer a comprehensive assessment of the effectiveness of EmONC investments after eight years (i.e., from 2017) of programmatic activity and suggest that Burundi continues to face significant structural challenges including resource prioritisation and allocation. Similar issues persist across many LMICs which struggle to optimise resource allocation[292-294,399,400] despite policy efforts and strategic investments aimed at addressing resource shortages and maldistribution.[292]

The subsequent fifth Chapter focused on evaluating EmONC competence among delivery care providers, including those who had previously received the routine (biennial) EmONC training and those who had never been trained before. Evidence consistently demonstrates that effective MNH service coverage depends on providers possessing the necessary skills to perform both basic and advanced lifesaving interventions such as resuscitating newborns and managing maternal bleeding.[205,401,402] Examining EmONC competence was particularly pertinent because research continues

to reveal skill deficiencies among delivery care professionals in LMICs, even among those with formal qualifications,[150,151] and because the current Burundian EmONC training curriculum targets doctors, midwives, and nurses collectively without distinguishing levels beyond caesarean section and blood transfusion; interventions that require medical expertise.

Moreover, given the high costs associated with this routine EmONC training and its uncertain impact, an assessment was essential to inform policy action and resource allocation. Working with MNH experts (Supplemental materials 3 and 4), I designed clinical vignettes tailored to the Burundian EmONC training curriculum and the professional skillset expected from each cadre. I evaluated over 90% of delivery care providers across the EmONC network and compared classical, traditional frequentist analytical methods with the merits of the IRT approach. Results indicated that providers generally exhibit deficient EmONC competence with the expected skillset significantly decreasing among lower-qualified cadres. For instance, I proved that random samples of doctors, midwives, and nurses would score 62% (71/115 successes), 57% (65/115 successes), and 45% (52/115 successes) respectively on my EmONC competence test instrument. Interestingly, I showed that the most challenging care areas where most providers lack adequate skills are the management of fever and malaria, postpartum haemorrhage, and hypertensive disorders which remain prominent maternal and indirectly newborn killers both locally in Burundi[403-406] and globally.[279,407,408]

Most importantly, as shown in Table 5.4, I identified substantial variations in EmONC competence within the same provider category with for instance a set of doctors demonstrating near-perfect proficiency in clinical management of severe preeclampsia and eclampsia while others exhibited severe deficiencies in handling these life-threatening obstetric complications. This pattern of disparity was observed across most clinical vignettes and among all cadre types. Furthermore, my analysis confirmed that the current Burundian standard EmONC training does not statistically augment the competence of doctors and midwives, but it does enhance that of nurses. These findings have important policy implications, highlighting the urgent need to redesign EmONC

training modules and develop tailored competence assessment tools for each cadre category.

In Chapter 6, I developed and implemented a framework designed to prioritise EmONC facilities based on workload patterns (i.e., deliveries and complications), available human resources, and mortality rates. Although my primary focus in this Chapter was on human resources, I did not overlook physical, non-human resources that I identified in Chapter 4 as they are indispensable for enhancing the overall readiness of maternity settings. First, I demonstrated that the current B/CEmONC facility classification in Burundi does not align with practice by demonstrating that some BEmONC facilities possess the capacity to perform CEmONC 'signal functions' such as caesarean section or blood transfusion while others are much busier than many CEmONC facilities, contradicting the standard hierarchical design of an EmONC system. Conversely, I detected several CEmONC facilities that lack a medical doctor and cannot therefore perform advanced care such as caesarean sections or blood transfusions. Second, I identified a set of 24 EmONC facilities managing high workloads with limited resources which I suggest could be prioritised for targeted investments in the face of budget constraints. Together, those 24/112 facilities handle 30% of all deliveries and manage 35% of complicated deliveries but employ only 15% of available staff. Finally, I found that the available data on maternal mortality is highly variable, likely inaccurate, and at present unhelpful for facility prioritisation.

In the seventh Chapter, I integrated information from previous chapters and employed a Decision Tree model to estimate the costs and predicted health benefits of different workforce investment scenarios developed collaboratively with stakeholders. In fact, to better assist policymakers in their evidence-based decision-making processes, such empirical evidence on the anticipated costs and expected gains (i.e., expressed as the number of maternal lives saved) is required.[409-411] First, findings reinforced the early results from Chapters 4 and 6, emphasising workforce shortages and maldistribution across EmONC facilities based on workload pressures. I projected that without an investment, Burundi's EmONC network could see approximately 3,208 maternal deaths annually out of an estimated 170,819 deliveries, which corresponds to about 1,878 maternal deaths per 100,000 deliveries (i.e., MMR). On the other hand, allocating US$

11.1 million over five years to address current staffing deficits relative to workloads could save approximately 532 maternal lives each year, reducing MMR from 1,878 to 1,546 maternal deaths per 100,000 deliveries. Further investment alternatives are pertinent under budget constraints. The first, adding two midwives in each EmONC facility with a workforce deficit, is expected to save 267 maternal lives annually from the estimated 160,384 deliveries happening in those facilities at the expense of about US$ 0.64 million. The second, focusing limited resources to the 24 priority facilities is projected to avert 163 maternal deaths among the 49,134 mothers delivering in those facilities each year at the expense of US$ 0.65 million. Comparison of alternative options revealed that adding two midwives to each of the 104 EmONC facilities with a staffing deficit is likely more cost-effective, nearly halving the cost per each maternal life saved compared to other alternatives (see Table 7.5). However, this impact assumes that other inputs are adequately available and that the maximum reduction in MMR is 21.3% if a facility changes from being grossly understaffed to being fully staffed.

8.2. Implications for the routine EmONC training

The Burundian EmONC policy mandates that all delivery care providers undergo an initial EmONC training course upon entering their roles to hone their skillset with refresher training every two years throughout their careers. The training content is standardised across cadres (doctors, midwives, and nurses) and comprises two main sections; a general component and a health condition-specific component. Broadly, the training emphasises comprehensive childbirth monitoring and the management of the active phase of labour including early recognition of warning signs indicative of potential obstetric complications, alongside a set of quality standards aimed at ensuring aseptic delivery practices. Specifically, the curriculum covers the management of various health conditions such as malaria, HIV positive women, postpartum haemorrhage, hypertensive disorders, obstructed and prolonged labour, incomplete abortion, and neonatal resuscitation, as well as essential newborn care. Additionally, doctors receive supplementary training on emergency caesarean section and blood transfusion in separate sessions. Typically, this training is conducted in a residential

format where professionals gather at a training centre for extended periods, which significantly increases costs; estimated at approximately BIF 23,821,369 (US$ 8,131.99) to train one provider (see Supplemental material 12).

I demonstrated in Chapter 5 that the vast majority of providers across Burundian EmONC facilities regardless of their prior EmONC training lack the full range of necessary skills to effectively manage obstetric and neonatal complications. Furthermore, unlike medical doctors, I found that the routine EmONC training has a positive impact on the competence of lower cadres; especially nurses. These findings have important policy implications. There is a need to review this training curriculum to better tailor its content for medical doctors and separate modules for midwives and nurses, or alternatively, to combine doctors and midwives into a unified training programme. Midwives often displayed competence levels comparable to or slightly exceeding that of doctors in many areas. Such a redesign of the EmONC training module should inform budget revisions and, instead of organising a residential training where trainees spend prolonged periods onsite receiving long-format lecturing which further disrupts service provision, policymakers should think to reorganise this training in form of a visiting programme involving senior professionals from CEmONC facilities regularly visiting juniors at BEmONC facilities for short stays to provide mentorship, coaching, and supervision. There are other formats of provider skills enhancement that can inspire Burundian policymakers in their efforts to redesign the EmONC training. One of these is the high-dose low-frequency programmes that are based on regular, short-term skills building and coaching within the work environment (usually a clinical ward) which have shown promise to improve the quality of care in resource-limited settings.[412-414] Instead of enhancing the capacity of one selected trainee who participates in a residential course, such a facility- and ward-delivered training and mentorship approach fosters a supportive learning environment within the healthcare setting, thus offering opportunities for professional development and quality improvement for all staff working in the target ward.[415] This approach would further reduce the costs while enhancing practical skills and on-the-field competence through hands-on training tailored to daily, facility-specific challenges. Additionally, the proposed senior visiting

programme would help strengthen connections between smaller and high-level facilities therefore paving the road for better referral networks.

8.3. Implications for the routine EmONC monitoring

Since the EmONC network establishment in 2017, Burundi has conducted routine EmONC monitoring every three months, supported primarily by UNFPA. This routine monitoring involves training data collectors and conducting field visits, incurring significant costs with each round requiring on average and based on historical expenditure pattern approximately US$ 103,576.45 (see Supplemental material 13). Therefore, assuming that this monitoring was consistently implemented as planned, we can estimate a budget amounting to approximately US$ 2.9 million to have been poured into routine EmONC monitoring from 2018 until 2024. However, historical patterns reveal that the collected databases are typically summarised in Excel spreadsheets without translating produced information into practical actions. The monitoring process is mainly carried out by the MoH RMNCAH programme together with donors, often without engaging relevant policymakers or MNH stakeholders on a wider spectrum. While regular monitoring is an important aspect of quality improvement processes,[416] investing such a substantial budget on data collection for the sole purpose to identify huge capacity deficits four times every year without subsequent interventions raises questions about effectiveness. This is especially true in a low-income country like Burundi where the total health expenditure is about US$ 112.4 million with a per capita health spending of about US$ 9 per capita and where I showed in Section 7.4 (Chapter 7) that an investment of US$ 0.64 million per year on staff might save approximately 267 maternal lives.

Concerning data quality and completeness, I showed in Chapters 6 and 7 that routine death records particularly for newborns are generally missing. Where they exist, maternal annual reported deaths showed unclear patterns, pointing to possible data quality issues. For instance, records indicated in Figure 6.3 that 31 EmONC facilities including those performing about 3,000 deliveries and managing around 1,500 complications in a year did not record a single maternal death which is highly unlikely

in the context of Burundi. Moreover, neonatal records are either completely non-existent or incomplete, which reflects a longstanding negligence of neonatal health monitoring.[352,417-419] In the same perspective, a regional WHO analysis that mapped and reviewed the Maternal and Perinatal Death Surveillance and Response (MPDSR) across 47 sub-Saharan African countries found that greater emphasis is often placed on maternal health with insufficient attention given to neonatal outcomes.[420,421] These findings therefore have a significant policy implication which we will address in the final policy debate by recommending improvements in maternal death reporting and the systematic recording of neonatal care data.

These issues reveal a critical need for Burundi to strengthen its data reporting system (i.e., the Health Management Information System; HMIS) to ensure accurate, timely, and comprehensive health data collection and management. Reliable and timely data are essential for informed decision-making, allocating resources, and monitoring progress towards health goals.[422,423] Improving HMIS infrastructure, training healthcare workers in data management, and establishing standardised reporting protocols are vital steps for enhancing data reliability. Thus, strengthening HMIS will support better planning and policy development and enable more targeted interventions, ultimately leading to improved health system performance and better health outcomes.

To connect global guidelines with my findings, I begin with the reminder that the WHO EmONC handbook and other global guidelines define EmONC facility types based on a set of signal functions performed, as outlined in Table 1.3. The handbook also includes a series of indicators to ensure that facilities providing EmONC services are adequately staffed and strengthened, properly distributed and accessible particularly to women at high risk of obstetric complications.[424] Routine EmONC facility assessments worldwide thus follow the WHO recommendations by focusing on documenting the provision of signal functions over a period of three months with facilities that have fully performed specific functions over this period being classified as 'EmONC functional'.[94,271,425-427] My argument, which corroborates other research evidence,[428] is that this approach has several inherent limitations and offers therefore very limited understanding of systemic challenges as such assessments fail to evaluate underlying issues or provide policy-relevant insights to guide decision-making.

Recent meta-narratives exploring EmONC signal functions for MNH service monitoring underscore that the main critique of this approach concerns the oversimplification of complex health system dynamics.[429] One of the major shortcomings is its failure to distinguish between facilities that do not perform a given signal function because there is no demand for that service and those that cannot perform it despite demand due to capacity constraints. On the one hand, labelling a designated EmONC facility as "non-functional" simply because no obstetric emergencies occurred during the assessment period can misrepresent facility performance and imply challenges that do not actually exist. On the other hand, designating EmONC facilities as "non-functional" when they cannot perform certain functions due to structural constraints and resource shortages even with high service demand masks genuine service gaps and overlooks real capacity needs.[429]

Furthermore, the binary nature of signal functions which classifies facilities as functional or not does not account for variations in the quality of care or performance levels thereby overlooking important nuances such as how well services are delivered. For instance, facilities that manage to perform all required functions even with poor or substandard quality (e.g., significant delays, clinical errors, etc.) are grouped together with those that perform efficiently and effectively limiting therefore the ability of policymakers and programme managers to identify high-performing facilities for best practice dissemination or to target quality improvement efforts where they are most needed.[429] In conclusion, these limitations suggest that decisions based solely on the EmONC signal functions risk being superficial or even misleading, potentially directing resources where they are not most needed.

The above limitations suggest that while the signal functions framework has played a valuable role in establishing a baseline metric for assessing EmONC service availability, it is insufficient on its own to guide comprehensive health system strengthening efforts. Moving forward, my research unveils the need for concerted efforts to develop robust, integrated, routine data collection and analysis systems that provide policymakers with actionable insights into both demand and capacity issues. Only then can we ensure that efforts to improve MNH are rooted in a clear understanding of systemic challenges and are capable of delivering high-quality, equitable care across all settings. Indeed, well-

designed and evidence-informed interventions have proven to effectively reduce MMR. For instance, the E-MOTIVE study and subsequent randomised trials that investigated the effect of early detection and treatment of PPH provided compelling evidence that timely interventions significantly reduce maternal mortality.[430] This evidence, which has been confirmed in ancillary studies, proved that implementing rapid response protocols, such as early identification of excessive bleeding and prompt administration of life-saving treatments such as uterotonics, blood transfusion, and surgical interventions markedly decreased the risk of maternal death associated with PPH. Such trials underscore the effectiveness of EmONC protocols in averting maternal death in diverse healthcare settings if implemented correctly.[431-433]

Based on the evidence from my studies, I support the shift in the global EmONC discourse to a focus on how countries can tailor and redesign their systems to reflect local realities and implement effectively rather than rigidly adhering to a perceived universal standard or strategy. Without regional or country-specific adaptations, global policies are less likely to help LMICs achieve meaningful improvements in maternal and neonatal health outcomes. I argue, this requires a learning systems approach embedded in local institutions where indigenous roles are recognised. This connects to the broader, increasing decolonial movements in global health and the suggestion that effective delivery of health programmes in LMIC contexts should be based on empowered local leadership and actors, foundations that go beyond principles articulated in standard implementation science frameworks.[434,435]

8.4. Implications for future EmONC assessments

I developed comprehensive EmONC facility assessment tools which were thoroughly reviewed by MNH experts and further validated by national MNH stakeholders. These tools comprise an EmONC facility assessment tool (see Supplemental material 7), a client exit interview form (see Supplemental material 8), and an EmONC competence assessment tool (see Supplemental material 9). The facility assessment tool collects data on the general and maternity-specific infrastructure, the staffing patterns such as the number of staff and weekly shifts at both facility and maternity levels. It also

assesses performance of standard EmONC signal functions, the availability and functionality of maternal and neonatal care equipment, supplies, and medications, and reviews routine records of deliveries, maternal and neonatal complications, and deaths. This tool I developed was based on other existing tools (e.g., the SARA tool) which I adapted with and for Burundian policymakers and I have digitalised it for easy, possible future reuse.

The mothers' exit interview tool captures women's lived experiences from arrival in the facility until exit. It is purposively designed to gather information on care pathways, waiting times, and perceptions regarding quality of care including aspects such as respectful and humanised care, respect and support during care, communication, and perceptions of corruption. However, findings from this assessment showed that this tool has limited capacity to fully capture the real lived experiences of mothers. This limitation in my case was likely due to several biases such as the social desirability bias, the Hawthorne effect, and the fear of repercussions on future health care (e.g., maternal and child postnatal care); altogether making the appraisal of the actual lived experiences difficult using such a survey.[436] During preliminary data analysis, I observed that these biases may have resulted in overstated positive feedback (detailed summary results are provided in Section 5.3 of the Appendix 1) rendering therefore this assessment less useful and less informative for further thesis analyses. Consequently, I recommend that relying solely on mother exit interviews in the Burundian context may lead to an incomplete or distorted understanding of the quality of maternal care. While useful, the EmONC competence assessment tool was found to be inadequate for evaluating the clinical skills of medical doctors (see details in Chapter 5). Consequently, it should be revised in conjunction with updates to the EmONC training curriculum as suggested in Section 8.2 above. Overall, my study not only generated valuable evidence for policymakers and stakeholders but also contributed to the development of adaptable assessment tools that can be readily used and tailored for future evaluations.

8.5. Implications for the EmONC policy revision

I showed in Chapter 4 and Chapter 6 that the current Burundian EmONC policy and the B/CEmONC classification do not align with global standards. For example, the minimum human resource recommendations outlined in Table 4.2 are nearly three times lower than those suggested by FIGO[249] even though recorded workloads in Burundian facilities are on average twice those upon which the FIGO standards are based. Additionally, having a single delivery room with two delivery tables and eight maternity beds is insufficient for many Burundian BEmONC facilities especially considering that some of these facilities reportedly deliver more than five women daily (i.e., approximately 2,000 deliveries annually). Similarly, the policy indicates that CEmONC facilities should have two delivery rooms and four delivery tables which still remain suboptimal given current workloads. Most importantly, as shown in Table 4.2, the policy does not specify the number of incubators and neonatal cots required for BEmONC or CEmONC facilities. It is therefore clear that the current Burundian EmONC policy was not formulated based on projected workloads and therefore requires an urgent update to reflect this reality. This study therefore has helped to unveil these policy gaps which are essential to be addressed in order to ensure that facilities are appropriately equipped to meet workload demands and to enable provision of quality care as schematised in Figure 2.7.

8.6. Recommendations and future directions

I developed in Chapter 4 three costed investment scenarios aimed at strengthening EmONC facilities based on the normative and the Burundian expert suggested resource standards (minimum and maximum). These scenarios specify the types and quantities of essential resources required for quality EmONC care by facility type. The associated resource estimates and their corresponding budgets provide valuable insights into the current resource deficits across the EmONC network further highlighting their distributions at facility, district, and provincial levels. Thus, Burundian health policymakers and MNH stakeholders have clear information of which of the important

EmONC resources are lacking and can further locate these deficits at facility, district, and provincial levels. Even though these deficit estimates do not account for workloads variations at this stage of data analysis (this aspect was considered in Chapter 7), prioritising resource gaps linked to the maximum expert-suggested benchmarks for physical resources such as infrastructure, equipment, and essential amenities as detailed in Table 4.1 and Table 4.4 would be a crucial step towards enhancing EmONC facility capacity. Some of the issues identified were foundational and important to address such as poor power supply, sanitary facilities, water supply, and ambulance services in BEmONC facilities although these problems were less widespread compared to other resource shortages. For instance, as shown in Table 4.4, I found that 14 BEmONC facilities lack a public toilet within the maternity ward for caregivers, while another 9 facilities do not have a water tap in the maternity area. Additionally, 3 BEmONC facilities are without access to reliable power supply or direct access to ambulance services.

Subsequent analyses (i.e., Chapter 5) focused on human resources. I examined their EmONC competence to evaluate the effectiveness of the routine EmONC training. I showed that this training deserves a revision to better suit different cadres and proposed redesigning it into a visiting programme to improve efficiency and reduce the costs. Next, I identified a set of facilities that should be prioritised given limited resources, as they are severely understaffed despite handling exceptionally high workloads. Although mortality data did not allow us to directly assess whether these priority facilities experience higher death rates, existing evidence has shown that mortality strongly correlates with high workloads and resource shortages, a characteristic typical of limited-resource settings.[437,438] Finally, I developed four potential workforce investment options alongside their predicted costs and benefits, offering ample investment alternatives under both sufficient and constrained resources.

Building on these findings, my study has produced a wealth of evidence useful for policy discussions. I plan to leverage this information to advance the following agenda:

Materialising an EmONC investment: In collaboration with the study stakeholder committee (see Supplemental material 2), we will organise a national stakeholder forum to discuss findings and investment options. The future course of action will

depend on available or mobilizable funding including financial pledges from partners. This event will be organised by the MoH which through the stakeholder committee will identify key participants representing policy influencers and strategic partners for the EmONC programme. During the Forum, I will present the study findings highlighting current EmONC resource deficits, issues related to EmONC competence, and various investment proposals.

Revising and redesigning the EmONC policy and the routine training and monitoring systems: I will recommend to the MoH establishing a multistakeholder technical committee comprising MNH experts to review and address the identified gaps in the country's EmONC policy. This committee would oversee the redesign of routine monitoring and training programmes aiming to improve the network's performance and achieve significant cost savings that could be redirected towards strategic investments. Additionally, this committee will develop strategies to improve data reporting particularly for neonatal records which are often missing and maternal and neonatal death reporting which are critical for effective monitoring and decision making.

8.7. Implications for reshaping the global EmONC landscape

8.7.1. Changes in the maternal and newborn health landscape

Since its conceptualisation in the late twentieth century, EmONC has evolved through international guidelines and evidence-based practices aimed at strengthening health systems and improving outcomes. In the 1990s, WHO had begun to define the essential components of EmONC with emphasis being laid on the need for timely access to life-saving services such as skilled birth attendance, emergency obstetric interventions, and neonatal care.[52] Over the years, updates of EmONC guidelines have incorporated advances in clinical management, health systems strengthening strategies, and a greater focus on quality of care, equity, and sustainability.[439,440]

From around the 2010s, significant shifts have occurred in the landscape of maternal and newborn health. Many countries worldwide have experienced substantial increases

in institutional deliveries, driven by improved access to healthcare facilities, government incentives, and changing cultural norms.[439,440] However, these increases have not consistently translated into reductions in maternal mortality with maternal death rates reportedly remaining high despite higher facility-based births in many low-income contexts.[441] Consequently, quality improvement has since become a central focus for efforts aimed at reducing maternal and neonatal deaths.[70]

In recent years, the understanding of quality of care has evolved, drawing from human rights, health systems strengthening, and implementation science. These perspectives have fostered new norms, emphasising that quality of care must encompass both the technical provision of services and the patient's experience; a people-centred approach that prioritises respectful, responsive care.[98]

8.7.2. Aligning with other global maternal and newborn health initiatives

Since its design, the EmONC framework has been complemented by numerous global MNH initiatives, many of which rely on their own monitoring tools. To alleviate effort going into data collection to track progress, the EmONC framework has been designed to align with other MNH initiatives where possible with harmonised indicators and streamlined data collection processes. Notably, unlike some other MNH tools, the EmONC framework is not intended for global reporting or accountability but is rather a country-driven tool aimed at supporting national planning, monitoring, and analysis.

Chief among the aligned initiatives is The Every Woman Every Newborn Everywhere (EWENE) initiative, formerly known as The Every Newborn Action Plan and Ending Preventable Maternal Mortality (ENAP EPMM). This is a UN-led effort that assists countries in developing acceleration plans to achieve global targets for maternal, neonatal, and stillbirth reduction.[442-444] Considering the EmONC system and its users as dynamic and evolving over time, shaped by various internal and external factors, provides valuable insight that connects well with the MNH transition model and the policy and program tools that are based on it.[351,445,446] Although it is possible to identify retrospectively the stages countries have passed through from high to low mortality, practical experience in implementing service delivery has proven that there is no

universal model that can be externally imposed on a complex health system to hasten its progression through these transition stages.[447] This means that there is no service delivery system that can jump overnight to an imagined aspirational future without engaging in its own social, cultural, and political processes to get there.[448-450] Therefore, tools such as the EmONC framework facilitate a clear understanding of the problem by making its scope and dimensions more visible while also highlighting the importance of understanding its specific context.

Findings from this study align with the broader goal of service delivery redesign initiatives, many of them specifically prioritising MNH with a particular focus on improving access to EmONC services, which have been advocated by numerous global commissions and working groups on MNH.[70,451,452] My research thus complements and contextualises efforts of other national and global stakeholders.

8.7.3. Implications of my study to the global EmONC policy debate

Findings from my study resonate with current global EmONC policy debates. First, they underscore the need to move beyond mere expansion of coverage with facilities named as providing EmONC care and emphasise that these facilities must be adequately resourced to provide quality of care. Without this, increased facility-based delivery does not necessarily lead to significant reductions in maternal and neonatal mortality. This reinforces the call for integrating quality improvement and people-centred approaches into EmONC strategies, ensuring that EmONC facilities provide respectful, effective, and timely emergency care. Secondly, my work emphasises that policy and planning should take account of uneven distribution of workload among EmONC facilities and thus the importance of context-specific assessments for resource allocation. This will require that countries adopt more nuanced, data driven frameworks in prioritising investment in facilities based on actual service demand and current capacity rather than solely relying on normative designations. Such an approach could optimise resource use, enhance system efficiency, and improve outcomes. Thirdly, the recognition of limitations in current mortality data and potential reporting biases highlights the need for strengthening HIS. Indeed, reliable data are essential for accurate monitoring, evaluation and the policy formulation and resource allocation my thesis explores.[453]

This shift, recognising that a universal national approach may not be suitable for diverse settings, and that a mixture of service decentralisation, task-shifting, and enhancing referral systems to improve timely access to emergency care may all be required, is consistent with recent global recommendations. The 2025 WHO manual on maternal and neonatal health highlights the necessity of tailoring interventions to local epidemiological patterns, resource availability, and health system capacity.[454]

Other prominent concerns dominating current MNH debates are the cost-effectiveness and sustainability of health system strengthening initiatives, primarily in LMICs. With limited health budgets, LMICs are seeking efficient models to scale up EmONC services without overextending resources. Analyses have shown that strategies including task-shifting, mobile health interventions, and community-based outreach can extend the reach of EmONC especially in rural settings.[455-457] These approaches aim to optimise the use of available human resources and infrastructure to ensure that interventions are both affordable and sustainable in resource-constrained environments. In future policy discussions Burundi may need to innovate as it tries to improve MNH outcomes optimally with limited budgets.

8.8. Strengths and limitations

The first strength of this study is the strong stakeholder support which I gained from the beginning of the study design through to the present. The MoH took the lead by establishing three committees as demonstrated in Section 3.3; a permanent study stakeholder committee composed of MNH experts involved in the study with authorship credit of all related publications, a technical committee, and an advisory committee with the latter two supporting the review and validation of the study tools. These committees also supported efforts to secure funding from WHO. A second key strength is the study's design which employed multiple data sources and various data collection processes aimed at minimising bias. For instance, data collectors were trained medical doctors with maternity and EmONC experience and majority of them had previously conducted similar surveys during routine EmONC monitoring. The use of electronic data collection forms which were designed to allow only entries of valid

data further enhanced data quality. Thirdly, the study was conducted across all EmONC facilities and the competence assessment covered over 90% of providers in these facilities. Therefore, findings of this study reflect a universal picture of the Burundian EmONC network. Fourth and finally, the analyses performed in this study employed robust statistical approaches to ensure validity of findings. For instance, the IRT methodology allowed me to discriminate participants based on question difficulty levels and to predict the true, underlying competence, analysis traditional frequentist statistical methods cannot achieve. This represents an innovative analytical approach applicable to similar studies aiming to examine staff competence and skills. I also developed in the facility prioritisation a reasonable and replicable framework and demonstrated the applicability of advanced statistical methods including data treatment approaches to deal with data overdispersion such as the z-score method and data winsorization aiming to improve the robustness of results. Sensitivity analyses were also conducted throughout the study to examine uncertainties with an aim to strengthen validity of the estimates.

However, this study has some limitations. Particularly, I lacked neonatal data and relied solely on maternal records being forced to assume that quality maternal health care positively influences neonatal health outcomes.[351,352] However, this limitation is a useful learning that will be discussed during the forthcoming stakeholder discussions to improve data reporting. Another limitation pertains to equity as I was unable to analyse access disparities because my focus was limited to service supply. I did not intend to examine service demand or wealth distribution among populations accessing care. Additional weaknesses include uncertainties in statistical parameters which were often difficult to eliminate such as the evidence on the impact of midwifery interventions on mortality reduction in Chapter 7 even though this drew on global evidence. There were also potential limitations in the costing methodology in Chapter 4 which might have failed to capture true market values of various resources. Indeed, despite using multiple approaches including shadow pricing adjusted for Burundi's GDP deflator over five years preceding the study, it is possible that I did not accurately capture market values of some EmONC resources included in the costing.

The modelling approach that I implemented in Chapter 7 to estimate the costs and cost-consequences is subject to several limitations. For example, the parameters used to assess the impact of midwifery interventions on maternal mortality were derived from global 'ecological' modelling studies which may have limited applicability to Burundi's specific service delivery context. Additionally, I assumed in the analysis that proportionate reductions in maternal deaths resulting from additional midwives are uniform across all facilities without accounting for environmental or contextual factors such as their level of non-human resources that could influence outcomes at individual sites. Furthermore, the analysis was not a formal optimisation approach as it was limited to specific scenarios decided together with stakeholders based solely on the understanding of the local socioeconomic context, a process that could be subjective. Furthermore, I did not perform complex sensitivity analyses beyond using the minimum and maximum thresholds. For instance, I did not vary input parameters (e.g., expected MMR reductions) based on the 95% CI threshold or triangular distributions and did not for instance progress other forms of analysis such as the frontier approaches which could have indicated under what range of circumstances additional staff would meet a specific cost-effectiveness threshold.

Decision analysis, the approach I used, can explicitly address decision-making under uncertainty by applying theories of probability and expected utility.[458] It is most appropriate for modelling programmes where relevant events occur over a short timeframe or are evaluated through intermediate outcome measures,[459-461] with this approach assuming that the probabilities assigned to each branch or chance node are accurate and reflect the true likelihood of events, although these probabilities are conditioned on prior events in the pathway. Consequently, this assumption may oversimplify the complexity of real-word settings, where probabilities are often less precise and more context-dependent particularly in Burundian maternity facilities where I earlier diagnosed in Chapter 4 varying levels of resource gaps which are further uncorrelated with workload.

The University of York's Decision Modelling Group in their practical guide to decision-making in healthcare aimed at experts and policymakers outlines key practical considerations for implementing such an approach. The Group emphasises that

decision models inherently suffer significant uncertainties particularly regarding budget estimates, event timelines, and probability assumptions.[462] These cautions are especially relevant for contexts like Burundi where resource constraints and data limitations can further complicate model accuracy and reliability as illustrated in Chapter 6 and Chapter 7 but my findings remain nonetheless valuable for initiating health policy decision-making for the Burundian maternal and newborn domain.

8.9. Postdoctoral research perspectives and career plan

Although this study provided valuable insights into the Burundian EmONC network and explored ways to strengthen it despite limited resources, the work remains incomplete. This means that my research and career trajectory are only just beginning. I have been a full-time academic staff member at the University of Burundi's Faculty of Medicine since 2017, and I plan to return there when I complete my doctoral studies to continue advancing my research agenda. Most academic staff members at my Faculty are medical clinicians with limited research experience, and I will be only the second faculty member across the medical faculty with research training at doctoral level.

My ambition and career aim are to develop and strengthen my own research agenda focused on health systems and maternal and newborn health in Burundi and the African region. Following the stakeholder discussions which are planned after submission of the thesis, policy decisions will be made regarding how to redesign and improve the EmONC network including revising policies and revamping routine monitoring and training systems. These decisions will create an opportunity for a postdoctoral fellowship during which I intend to support Burundi's successful implementation of the EmONC agenda, document the effectiveness of any investments made, and examine their impact on equity. This postdoctoral research agenda will be a key step in my career development. If Burundi's EmONC programme effectively advances the MNH agenda under my leadership, I aspire to become an expert who can support other African countries and beyond the continent.

Conclusion

This study aimed to support Burundi in redesigning and improving its EmONC network by generating well-researched, robust evidence that permits health policymakers and stakeholders to begin to understand the key challenges facing this network along with possible solutions. In fact, despite eight years of programme implementation and significant funding primarily allocated to routine surveys and training, my research revealed in Chapter 4 critical capacity challenges that currently exist in these facilities, affecting both human and physical resources. The magnitude of capacity deficits indicates that the current EmONC facilities are often incapable to deliver quality care or significantly reduce maternal mortality as intended. To better help decision-makers realise the size of the problem, I estimated the costs associated with closing these capacity deficits and proposed three levels of governmental funding the country might choose to invest depending on the level of resource investment Burundi is willing to make.

Although I did not assess whether all 112 facilities are necessary, I suggested based on findings that Burundi may prioritise a subset of facilities for investment especially given limited resources and the likely inability to close all gaps across the network. I developed and implemented a framework that is relevant to other public health contexts which enabled me to classify facilities based on actual workload and existing resources alongside mortality data with the goal to identify those facing huge workloads with fewer resources. Although mortality data seemed unreliable in my context, the framework demonstrated how such facility grouping can capture mortality if accurate data is available. Using this approach, I was able to isolate a group of 24 facilities that in theory should be prioritised for targeted EmONC investment. However, further decision analyses in Chapter 7 showed that investing in these facilities does not present special value suggesting therefore that any targeted investment should be discussed with stakeholders.

Furthermore, I developed four EmONC investment scenarios alongside the cost and benefit estimates of each. These investment scenarios, formulated with inputs from the study stakeholders (see Supplemental material 2), represent plausible options Burundi could pursue to meet its goal of reducing maternal and neonatal mortality.

Finally, findings revealed that the current EmONC training which is supposedly delivered every two years may not significantly improve hands-on competence of delivery care providers as those who were examined (who represented more than 90% of the total available workforce) demonstrated inadequate EmONC skills regarded of prior EmONC training. Most importantly, despite limited evidence of its impact, I showed in Section 8.2 that this training is highly costly.

In conclusion, since my study is supported by MNH stakeholders with the lead of the MoH, we will organise a policy meeting to review all my findings and develop evidence-informed strategies to strengthen this network. While policymakers and stakeholders will decide based on the most feasible investment options and linked budget constraints, findings from previous Chapters suggest that adding a limited size of workforce alongside addressing physical resources would be cost effective if fully addressing all workforce and material deficits is not possible. Furthermore, Burundi needs to strengthen its HIS so that any investment made (or EmONC network redesign) is properly evaluated to learn if the intended goal (i.e., MMR, NMR, and stillbirth reduction) is being achieved. As detailed in Section 8.9, I remain committed to supporting Burundi's progress towards achieving its MNH goals through continued research including pursuing a postdoctoral fellowship or research grant with assistance of my doctoral Supervisors.

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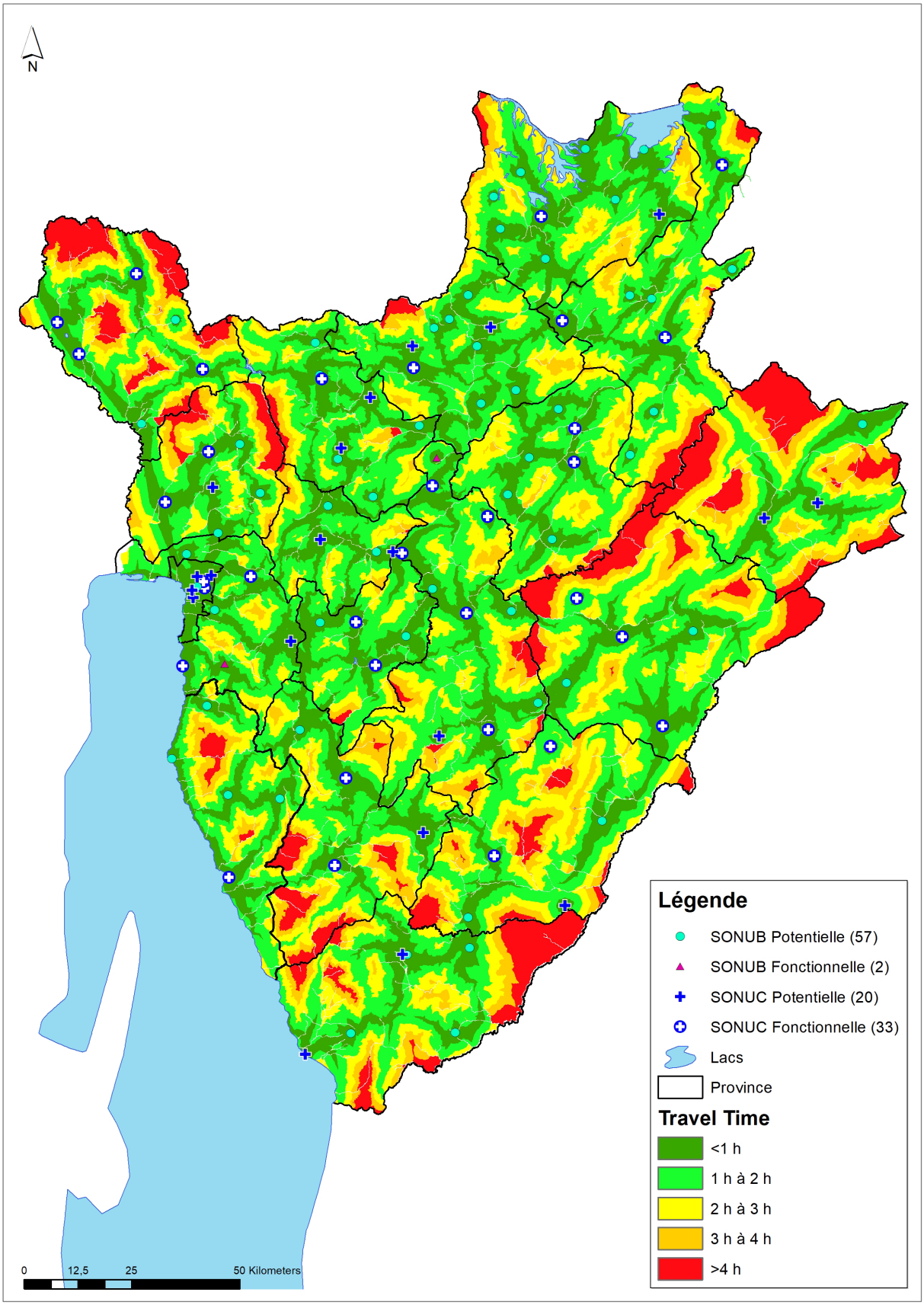
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Supplemental material 1. Geographic distribution of Burundian EmONC facilities



Supplemental material 1 is the map of Burundian EmONC network in 2020. The map shows that three years after the creation of the network only 2 BEmONC and 33 CEmONC facilities where functional implying that over a period of three months preceding the survey, 57 BEmONC facilities did not offer the whole set of seven signal functions and 20 CEmONC facilities failed to offer the full set of nine signal functions. 'Lacs' stands for 'Lake Tanganyika'.

Supplemental material 2. Members of the permanent study stakeholders committee

Local Stakeholder Committee for a doctoral research project on Maternal and Newborn Health in Burundi

Background

Desire Habonimana, a doctoral student at the University of Oxford, is conducting a doctoral research in Burundi under collaboration and supervision of Mike English, Catia Nicodemo and Attakrit Leckcivilize. The project title is:

"Examining and addressing the structural and workforce challenges facing Burundi's Emergency Obstetric and Neonatal Care (EmONC) Network"

The objective of this note is to form a local stakeholder committee that will permanently oversee and contribute to the research programme during the study design, delivery, and reporting and dissemination of findings.

Local stakeholder committee members

The local stakeholder committee comprises policymakers, researchers, donors, and implementers involved in maternal and newborn health. The committee shall be made up of between 6 and 8 individuals who will serve as "independent experts" providing expert opinion related to the research design and conduct. The committee will meet as per needed, upon requested by the PI (Desire Habonimana). The place and time of the meeting should be agreed upon and each meeting should not exceed 2 hours. The committee members are listed below:

Names	Institution
1. Dr Jean Baptiste NZORIRONKANKUZE	Ministry of Health (MSPLS)
2. Dr Ananie NDACAYISABA	Director, PNSR (MNCAH)
3. Prof Sylvestre BAZIKAMWE	University of Burundi
4. Dr Zacharie NDIZEYE	University of Burundi
5. Dr Eugenie Siga Diane NIANE	WHO
6. Dr Aristide BISHINGA	JICA
7. Dr Donavine UWIMANA	ABUBEF

Many thanks,

Desire Habonimana
DPhil student
Nuffield Department of Medicine
University of Oxford
E-mail : desire.habonimana@univ.ox.ac.uk
Tel. +257 61 700 576 or +44 7400 769460

Supplemental material 3. Study technical committee members

REPUBLIQUE DU BURUNDI

Bujumbura, le...23/5/2022

MINISTERE DE LA SANTE PUBLIQUE
ET DE LA LUTTE CONTRE LE SIDA
CABINET DU MINISTRE

N° 630 /...2657/CAB/2022

V/ Réf/

N/ Réf/

Objet :

Aux Docteurs,
- KUBWIMANA Zacharie, DPSE
- BIGAYI Théophile, PNSR
- NIJIMBERE Josiane, PNSR
- MUGISHA Jean Claude, PNSR
- NKURUNZIZA Innocent, SP
- NAHAYO Anaclet, DSNIS

A Madame/Monsieur :
- GAHUNGERE Olivier, PNSR
- NZEYIMANA Thierry, PNSR
- HABONIMANA Daniel,PNSR
- BUCUMI Souvérienne, PNSR
- NDAYIZIGA Rose Simone, PNLS/IST
- NDUWARUGIRA Thérence, UNFPA

Nomination du comité technique de l'enquête SONU dans les 112 maternités du réseau SONU du Burundi

Docteur, Madame, Monsieur,

J'ai l'honneur de vous informer que vous êtes nommé membre du comité technique de l'enquête SONU dans les 112 maternités du réseau SONU du Burundi.

La présidence, la vice-présidence et le Secrétariat seront respectivement assurées par Dr KUBWIMANA Zacharie, GAHUNGERE Olivier et Dr BIGAYI Théophile.

Vous trouverez, en annexe à la présente, les termes de références dudit comité.

Veuillez agréer, Docteur, Madame, Monsieur, l'assurance de ma considération distinguée.

LE MINISTRE DE LA SANTE PUBLIQUE
ET DE LA LUTTE CONTRE LE SIDA

Dr Sylvie NZEYIMANA

P.O. Secrétaire Permanent

Cabinet du Ministre
B P 1820
BUJUMBURA

Le 23/5/2022

B.P 1820 Tél. (257) 22 22 91 95/ (257) 22 24 25 42-BUJUMBURA

Supplemental material 4. Study steering committee members

REPUBLIQUE DU BURUNDI

Bujumbura, le 23/5/2022

MINISTERE DE LA SANTE PUBLIQUE
ET DE LA LUTTE CONTRE LE SIDA
CABINET DU MINISTRE

N° 630 /265/CAB/2022

V/ Réf/

N/ Réf/

Objet :

Nomination du Comité de pilotage de l'enquête SONU dans les 112 maternités du réseau SONU du Burundi

Aux Docteurs,

- NZORIRONKANKUZE Jean-Baptiste, SP
- NTIHABOSE Oscar, DGOSA
- NDACAYISABA Ananie, PNSR
- BAZIKAMWE Sylvestre, AGOB
- NDAYISENGA Jeanine, ABUNE
- MAGONYAGI Yolande, UNFPA
- NINA Siga Eugénie, OMS
- NDELEMA Brigitte, OMS
- BISHINGA Aristide, JICA
- NTAKIRUTIMANA Dorothée, UNICEF

A Madame

- MUHIMBARE Nadine, Cabinet du MSPLS

Docteur, Madame,

J'ai l'honneur de vous informer que vous êtes nommé membre du comité de pilotage de l'enquête SONU dans les 112 maternités du réseau SONU du Burundi.

La présidence, la vice-présidence et le Secrétariat seront respectivement assurées par Dr NZORIRONKANKUZE Jean Baptiste, Dr NTIHABOSE Oscar et Dr NDACAYISABA Ananie.

Vous trouverez, en annexe à la présente, les termes de références dudit comité.

Veuillez agréer, Docteur, Madame, l'assurance de ma considération distinguée.

LE MINISTRE DE LA SANTE PUBLIQUE
ET DE LA LUTTE CONTRE LE SIDA

Dr Sylvie NZEYIMANA

P.O. Secrétaire Permanent

RÉPUBLIQUE DU BURUNDI
Cabinet du Ministre
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Le 23/5/2022

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Supplemental material 5a. Ethical Certificate from University of Burundi (original)

UNIVERSITE DU BURUNDI

FACULTE DE MEDECINE

COMITE D'ETHIQUE ET DE RECHERCHE EN SANTE HUMAINE

Réf : FM/CE 04/.M/2022 Bujumbura le 15 février 2022

Au Docteur **Dr Désiré HABONIMANA**
Etudiant en PhD à l'Université d'Oxford
A Oxford, Angleterre

Objet : Octroi d'un certificat d'éthique pour votre travail de recherche

Monsieur le Docteur,

Nous avons l'honneur de porter à votre connaissance que le Comité d'Ethique de la Faculté de Médecine de l'Université du Burundi marque son accord à votre demande d'approbation d'un protocole de recherche intitulé : **« Addressing the need for an appropriate skilled delivery care workforce in Burundi to support Maternal and Newborn Health Service Redesign (MNH-Redesign) ».**

Le Comité tient à vous faire savoir que l'étude s'effectuera dans un délai ne dépassant pas la durée de vos études doctorales (5 ans) et que la collecte et le traitement des données resterons de stricte avec le protocole de confidentialité.

Dépasser ce délai, une nouvelle demande d'approbation est requise.

Veuillez agréer ; Monsieur le Docteur, l'assurance de notre considération distinguée.

Pour le Comité d'Ethique,

Professeur Rénovat NTAGIRABIRI

Président.

Comité Institutionnel de Bio-Ethique
CHU-Kamenge
Faculté de Médecine
Université du BURUNDI
B.P.: 1020

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Supplemental material 5b. Ethical Certificate from University of Burundi (translated)

UNIVERSITY OF BURUNDI

FACULTY OF MEDICINE

Bujumbura, February 15th, 2022

HUMAN HEALTH RESEARCH ETHICS COMMITTEE

Dr Désiré HABONIMANA
PhD Student
Oxford University
Oxford-UK

Re: Ethics Certificate Delivery
for your Research

Dear Sir,

I am pleased to inform you that the Ethics Committee of the Faculty of Medicine approves your request of research protocol entitled: "**Addressing the need for an appropriate skilled delivery care workforce in Burundi to support Maternal and Newborn Health Service Redesign (MNH-Redesign)**".

It is worth mentioning that your study will have to be carried out within a period not exceeding the duration of your doctoral studies and that the collection and data processing should be done in a strict respect of your protocol and confidentiality.

Once the duration of your doctoral studies exceeded, a new request will be required.

I look forward to hearing from you soon.

Faithfully yours,

President of the Faculty Ethics Committee,

Pr Rénovat NTAGIRABIRI
(Signed)

Translated by the Faculty Academic Secretariat
Ferdinand NCABWENGE
e-mail: Ferdinand.ncabwenge@ub.edu.bi

Supplemental material 6. Ethical Certificate from University of Oxford

Oxford Tropical Research Ethics Committee

University of Oxford
Research Services, Research Governance, Ethics & Assurance
Boundary Brook House, Churchill Drive, Oxford OX3 7GB
Tel. +44 (0)1865 (2)82106
E-mail: oxtrec@admin.ox.ac.uk

Dr Desire Habonimana
University College
Oxford, OX1 4BH

23 April 2022

Dear Dr Habonimana

Full Title of Study: Addressing the need for an appropriate skilled delivery care workforce in Burundi to support Maternal and Newborn Health Service Delivery Redesign (MNH-Redesign)

OxTREC Reference: 516-22

Thank you for your email of 23 April 2022, and for your updated minimal risk application form.

I am pleased to confirm that approval has now been granted for this study. This is valid for the planned duration of the study as detailed in the application.

The documents approved for this study are as follows:

Documents:	Version:	Date:
Data collection tools	1.0	21 March 2022

Any subsequent changes to the application must be submitted to the Committee as an Amendment. This should include a letter to give the reasons for the proposed modifications and all revised documents with changes tracked.

Please ensure that you submit a completed Annual Report form on every anniversary of this approval and a final End of Study Report. The relevant forms can be found on the OxTREC website.

Finally, please note the following **important information**:

Data safety—all studies
It is the responsibility of the PI to ensure that all data collected during the course of the study is stored and transferred safely and securely. Further guidance and advice are available from the Research Data Team.

Yours sincerely

DocuSigned by:
BA168DF4624B463...

Dr Karen Melham
Sponsorship and Ethics Lead
for
Research Ethics Manager, OxTREC

Tel: +44 (0)1865 (2)82106
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Evaluation empirique des besoins en soins maternels et néonatals d'urgence dans le réseau SONU au Burundi

OUTILS DE COLLECTE DE DONNÉES

TROUVER LE RÉPONDANT (e.g., la personne responsable de la FOSA / département, l'agent de santé le plus senior responsable des salles de travail, la femme qui a récemment accouché).

LIRE LA DÉCLARATION SUIVANTE :

Bonjour / bon après-midi ! Mon Nom est _____. Nous sommes ici au Nom du Programme National de Santé de la Reproduction (PNSR) du ministère de la Santé Publique et de la Lutte contre le SIDA qui veut mener une évaluation pour comprendre la capacité de toutes les FOSA du réseau SONU au Burundi. Les objectifs de l'évaluation sont :

- *Evaluer l'état de fonctionnement global des FOSA par rapport aux standards nationaux et internationaux*
- *Évaluer la qualité des soins offerts et la satisfaction des utilisateurs des services de santé maternels et néonatals d'urgence*
- *Evaluer les compétences en SONU du personnel qualifié et estimer l'écart de main-d'œuvre selon la méthode WISN (Workload Indicator for Staffing Need).*

Ces informations aideront le ministère est ses partenaires à mieux planifier les services SONU au Burundi. Vous participez à cette évaluation car nous pensons que vous êtes la personne la plus appropriée pour nous faire part de vos commentaires [ou vous êtes le résultat d'un processus aléatoire]. Les informations que nous recueillons seront partagées avec les autorités compétentes au Burundi, y compris les parties prenantes et les décideurs, et par le biais de publications. Ni votre nom ni celui de toute autre personne de cette FOSA ne seront inclus dans l'ensemble de données ou dans un rapport. Nous sollicitons votre aide pour nous assurer que les informations que nous collectons sont exactes. Vous êtes libre de refuser de répondre à toute question ou de choisir d'arrêter l'entretien à tout moment. Si vous trouvez qu'il y a une question à laquelle vous n'êtes pas compétent pour répondre avec précision ou pour laquelle quelqu'un d'autre est la personne la plus appropriée pour fournir les informations, nous apprécierions de bien vouloir nous présenter à cette personne pour nous aider à collecter des informations précises. Avez-vous des questions à ce stade ? Ai-je votre accord pour continuer ?

OUI		**NON**			
JOUR	**MOIS**	**ANNEE**	……	……	**2022**

SECTION 1 : DISPONIBILITÉ ET FONCTIONNALITÉ DES FOSA DU RESEAU SONU

Code de l'évaluateur : ____ |____ [deux chiffres numériques plus deux chiffres alphabétiques]

Date de la collecte : ____ |____ |____ [Jour | Mois |Année]

Coordonnées géographiques : _____ |_____ [latitude | longitude]

LORSQUE VOUS AVEZ REÇU LE CONSENTEMENT, LISEZ CETTE DÉCLARATION.

J'ai quelques questions à poser, et toutes concerneront la formation sanitaire. Tout d'abord, je vais demander des informations générales sur la FOSA. Deuxièmement, je poserai des questions spécifiques concernant les infrastructures de base, le personnel général et le personnel travaillant spécifiquement dans les salles d'accouchement, le nombre des accouchements et des complications néonatales, y compris les décès, le système de référence et l'équipement, le matériel et les fournitures de soins d'accouchement. Enfin, je rencontrerai quelques personnels des maternités pour leur poser quelques questions sur les tâches qu'ils accomplissent dans le cadre de l'accouchement. Si nécessaire, je demanderai accès aux registres de maternité pour collecter des informations supplémentaires ou de vérifier les réponses qui m'auront été fournies verbalement. J'espère que tout va bien. Si vous avez des questions, n'hésitez pas à me demander.

ÉVALUATION DES ÉTABLISSEMENTS DE SANTÉ

Données collectées auprès des responsables des établissements de santé, des responsables des ressources humaines, des responsables de la logistique et/ou des responsables des salles de travail

I. IDENTIFICATION DE L'ETABLISSEMENT DE SANTE

QN	Question	Réponse
101	Nom de l'établissement de santé	_____
102	Type de l'établissement de santé	1. _____ [Centre de santé] 2. _____ [Hôpital de District] 3. _____ [Hôpital régional] 4. _____ [Hôpital national]
103	Est-ce que cette FOSA a été transformée comme Hôpital communal ?	1. _____ [Oui] 2. _____ [Non]
104	Nom du District sanitaire	_____
105	Type de résidence (lieu)	1. _____ [urbain] 2. _____ [rural]
106	Statut de la FOSA	1. _____ [Publique] 2. _____ [confessionnelle] 3. _____ [privée] 4. _____ [autre, à préciser]
107	Taille de la population couverte	_____
108	Pour les CDS, quelle est la durée estimée du trajet (en voiture) d'ici à l'hôpital de référence (en minutes) ?	_____

109	Cet établissement de santé est-il ouvert 24h sur 24 les 7 jours sur 7 jours pendant les jours d'ouverture	1. _____ [Oui] 2. _____ [Non]
110	Si non, combien de jours par semaine cet établissement est-il ouvert ?	_____
111	Combien de personnel qualifié permanent est présent à cette FOSA (exclure les contractuels et visiteurs)?	1. Sage-femme____ 2. Infirmier(e)_____ 3. Médecin_____ 4. Gynécologue et Obstétricien_____

II. DISPONIBILITÉ DES INFRASTRUCTURES DE BASE

QN	Question	Réponse
	Infrastructure	
201	Est-ce cette FOSA dispose d'une source d'eau	1. _____ [Oui] 2. _____ [Non]
202	Si oui, laquelle des sources suivantes ?	1. ___ [canalisé dans l'établissement] 2. ___ [canalisé sur le terrain de l'installation] 3. ___ [robinets publics / bornes-fontaines] 4. ___ [forage] 5. ___ [puits creusé protégé] 6. ___ [puits creusé Non protégé] 7. ___ [eau de pluie] 8. ___ [autre précisez]
203	L'eau de cette FOSA est-elle sur place, à moins de 500 mètres ou au-delà de 500 mètres?	1. ___ [sur place / dans la FOSA] 2. ___ [à moins de 500 m de la FOSA] 3. ___ [au-delà de 500 m la FOSA]
204	Au cours des 7 derniers jours, y a-t-il eu un moment où il n'y a pas eu d'eau pour la FOSA pendant plus de deux heures d'affilée à partir de cette source la plus utilisée ?	1. ___ [Oui] 2. ___ [Non] 3. ___ [Je ne sais pas, pas de réponse]
205	Est-ce que cette FOSA dispose d'un téléphone fixe, d'un téléphone portable ou d'une radio à ondes courtes en état de marche, disponible pour appeler à l'extérieur à tout moment où les services aux clients sont proposés ? (il peut s'agir d'un appareil appartenant à l'établissement ou d'un téléphone portable privé d'un membre du personnel pris en charge par l'établissement)	1. ___ [Oui] 2. ___ [Non] 3. ___ [Je ne sais pas, pas de réponse]
206	Combien d'ordinateurs fonctionnels cette FOSA dispose-t-elle ?	1. _____
207	Y a-t-il un accès à Internet dans cette FOSA aujourd'hui ? (routeur/ modem) ?	1. ___ [Oui] 2. ___ [Non] 3. ___ [Je ne sais pas, pas de réponse]
208	Y a-t-il des toilettes (latrines) en état de fonctionnement qui sont disponibles pour une utilisation générale en consultation externe ?	1. ___ [Oui] 2. ___ [Non] 3. ___ [Je ne sais pas, pas de réponse]
209	Si OUI, laquelle ?	1. ___ [tirer la chasse / siège] 2. ___ [latrine à fosse améliorée ventilée VIP] 3. ___ [latrine à fosse avec dalle] 4. ___ [latrines à fosse sans dalle / latrines à ciel ouvert] 5. ___ [toilettes à compost]

		6. ___ [autre, spécifier]
210	Quelle est la principale source d'électricité de cette FOSA ?	1. ___ [réseau électrique] 2. ___ [générateur à essence] 3. ___ [générateur à piles] 4. ___ [système solaire] 5. ___ [autre, spécifier] 6. ___ [pas d'alimentation de courant]
211	Au cours des 7 derniers jours, à quelle fréquence l'électricité a-t-elle été disponible sur 24h à partir de la source principale ou de toute source de secours lorsque la FOSA était ouverte pour les services ?	1. ___ [toujours disponible, sans interruption] 2. ___ [souvent disponible, interruptions < 2h jour] 3. ___ [parfois disponible, inter. > 2h par jour] 4. ___ [Je ne sais pas]
212	Combien de salles d'opération la FOSA compte-t-elle (fonctionnelles et Non fonctionnelles) ?	_____
213	Combien de blocs opératoires sont-ils fonctionnels ?	_____
	Nombre de lits	
214	Combien de lits d'hospitalisation cette FOSA dispose-t-elle tant pour les adultes que pour les enfants ? (VEUILLEZ INCLURE TOUS LES LITS DE MATERNITÉ MAIS EXCLURE LES TABLES D'ACCOUCHEMENT)	1. ___ 2. ___ [Je ne sais pas, pas de réponse]
215	Parmi les lits d'hospitalisation de cette FOSA, combien sont des lits de maternité ? EXCLURE LES TABLES D'ACCOUCHEMENT	1. ___ 2. ___ [Je ne sais pas, pas de réponse]
216	Combien de tables d'accouchement cette FOSA dispose-t-elle ?	1. ___ 2. ___ [Je ne sais pas, pas de réponse]
217	Au cours des 3 derniers mois, une femme en travail ou après l'accouchement a-t-elle dû partager un lit avec une autre femme ou dormir sur un matelas à même le sol ?	1. ___ [Oui] 2. ___ [Non] 3. ___ [Je ne sais pas, pas de réponse]
218	Au cours des 3 derniers mois, une femme a-t-elle accouché sur le sol en raison du manque de lit?	1. ___ [Oui] 2. ___ [Non] 3. ___ [Je ne sais pas, pas de réponse]
219	Combien de lits dans cette FOSA sont consacrés aux soins aux nouveau-nés ?	1. ___ 2. ___ [Je ne sais pas, pas de réponse]
220	Parmi les lits d'enfant dédiés aux soins du nouveau-né, combien sont consacrés exclusivement aux nouveau-nés malades ?	1. ___ 2. ___ [Je ne sais pas, pas de réponse]
221	Cette FOSA dispose-t-elle d'une unité néonatale fonctionnelle ?	1. ___ [Oui] 2. ___ [Non] 3. ___ [Je ne sais pas, pas de réponse]
222	Combien de couveuses fonctionnelles sont disponibles pour les soins du nouveau-né dans cette FOSA ?	1. ___ 2. ___ [Je ne sais pas, pas de réponse]
223	Cette FOSA dispose-t-elle d'une unité néonatale de soins intensifs ?	1. ___ [Oui] 2. ___ [Non] 3. ___ [Je ne sais pas, pas de réponse]
224	Combien y a-t-il de lits dans l'unité néonatale de soins intensifs ?	1. ___ 2. ___ [Je ne sais pas, pas de réponse]

225	Cette FOSA dispose-t-elle d'une unité de soins intensifs fonctionnelle pour adultes ?	1. ___ [Oui] 2. ___ [Non] 3. ___ [Je ne sais pas, pas de réponse]
226	Combien de lits sont disponibles dans l'unité de soins intensifs pour adultes ?	1. ___ 2. ___ [Je ne sais pas, pas de réponse]
	Commodités de référence	
227	Cette FOSA dispose-t-elle d'une ambulance fonctionnelle pour le transport d'urgence des clients qui est stationné dans cette FOSA ou qui opère à partir de cet établissement ?	1. ___ [Oui] 2. ___ [Non] 3. ___ [Je ne sais pas, pas de réponse]
228	Cette FOSA a-t-elle accès à une ambulance pour le transport d'urgence des clients qui est stationné dans un autre établissement ou qui opère à partir d'un autre établissement à proximité ?	1. ___ [Oui] 2. ___ [Non] 3. ___ [Je ne sais pas, pas de réponse]
229	Au cours de la semaine dernière, la FOSA disposait-elle d'un stock de carburant?	1. ___ [Oui] 2. ___ [Non] 3. ___ [Je ne sais pas, pas de réponse]

III. PERSONNEL DE SOINS GÉNÉRAUX ET D'ACCOUCHEMENT

J'ai quelques questions sur le personnel de cet établissement. Veuillez me dire combien de membres du personnel possédant chacune des qualifications suivantes sont actuellement affectés, employés ou détachés dans cet établissement. Veuillez compter chaque membre du personnel une seule fois, sur la base de la qualification technique ou professionnelle la plus élevée. Veuillez ne pas inclure les étudiants qui suivent une formation dans l'établissement. J'aimerais également connaître le nombre de postes vacants et le nombre d'employés travaillant dans les unités de maternité et néonatologie.

	Discipline	a. Combien sont actuellement affectés, employés ou détachés dans cette FOSA, y compris le personnel contractuel ?	b. Combien ont un contrat avec cette FOSA ?	c. Combien sont actuellement en congé prolongé (plus d'un mois) ?	d. Combien de postes sont disponibles pour ce type de personnel selon vos normes et standards de dotation ?	e. Parmi personnel présent, combien travaillent actuellement dans la maternité / gynécologie / néonatologie ?	f. Parmi le personnel non en congé prolongé, combien fournissent actuellement des services de santé maternelle et infantile?
301	Docteur en Médecine	_____	_____	_____	_____	_____	_____
302	Spécialistes (TOUS)	_____	_____	_____	_____	_____	_____
303	Obstétriciens SEULEMENT	_____	_____	_____	_____	_____	_____
304	Pédiatres / Néonatologues	_____	_____	_____	_____	_____	_____
305	Chirurgiens	_____	_____	_____	_____	_____	_____
306	Anesthésistes	_____	_____	_____	_____	_____	_____
307	infirmiers (TOUS, exclus les sages femmes)	_____	_____	_____	_____	_____	_____
308	Sages femmes	_____	_____	_____	_____	_____	_____

Question à poser : Ce cadre de travailleurs est-il toujours disponible (physiquement présent ou sur appel ou non disponible) en cas d'urgence maternelle et/ou néonatale ?

QN	Item	Obstétricien / Gynécologue	Docteur en Medicine	Chirurgie	Pédiatre	Néonatologues	Sagefemme	Infirmier auxiliaire sage-femme	infirmier	Anesthésiste	infirmier Anesthésiste	Technicien de laboratoire
309	Du lundi au vendredi en journée ?	1__Au service 2__De garde 3__Indisponible	1__Au service 2__De garde 3__Indisponible	1__Au service 2__De garde 3__Indisponible	1__Au service 2__De garde 3__Indisponible	1__Au service 2__De garde 3__Indisponible	1__Au service 2__De garde 3__Indisponible	1__Au service 2__De garde 3__Indisponible	1__Au service 2__De garde 3__Indisponible	1__Au service 2__De garde 3__Indisponible	1__Au service 2__De garde 3__Indisponible	1__Au service 2__De garde 3__Indisponible
310	Du lundi au vendredi le soir ?	1__Au service 2__De garde 3__ indisponible	1__Au service 2__De garde 3__Indisponible	1__Au service 2__De garde 3__Indisponible	1__Au service 2__De garde 3__Indisponible	1__Au service 2__De garde 3__Indisponible	1__Au service 2__De garde 3__Indisponible	1__Au service 2__De garde 3__Indisponible	1__Au service 2__De garde 3__Indisponible	1__Au service 2__De garde 3__Indisponible	1__Au service 2__De garde 3__Indisponible	1__Au service 2__De garde 3__Indisponible
311	Samedi, dimanche et jours fériés en journée ?	1__Au service 2__De garde 3__Indisponible	1__Au service 2__De garde 3__Indisponible	1__Au service 2__De garde 3__Indisponible	1__Au service 2__De garde 3__Indisponible	1__Au service 2__De garde 3__Indisponible	1__Au service 2__De garde 3__Indisponible	1__Au service 2__De garde 3__Indisponible	1__Au service 2__De garde 3__Indisponible	1__Au service 2__De garde 3__Indisponible	1__Au service 2__De garde 3__Indisponible	1__Au service 2__De garde 3__Indisponible
312	Samedi, dimanche et jours fériés la nuit ?	1__Au service 2__De garde 3__Indisponible	1__Au service 2__De garde 3__Indisponible	1__Au service 2__De garde 3__Indisponible	1__Au service 2__De garde 3__Indisponible	1__Au service 2__De garde 3__Indisponible	1__Au service 2__De garde 3__Indisponible	1__Au service 2__De garde 3__Indisponible	1__Au service 2__De garde 3__Indisponible	1__Au service 2__De garde 3__Indisponible	1__Au service 2__De garde 3__Indisponible	1__Au service 2__De garde 3__Indisponible

IV. FONCTIONS SIGNALETIQUES SONU

INSTRUCTIONS :

Répondez aux questions suivantes concernant les fonctions signalétiques en interrogeant les responsables ou les agents de santé du service de maternité ou les responsables des FOSA, en examinant les registres des FOSA ou par l'observation. Pour de nombreuses questions, vous noterez si la fonction a été exercée au **cours des 3 derniers mois**, et si non, pourquoi elle n'a pas été exécutée. N'oubliez pas que « **parentéral** » signifie par injection, intramusculaire ou intraveineuse.

- **Problèmes de formation** : le cadre autorisé est disponible mais n'est pas formé, ou il y a un manque de confiance dans les compétences des prestataires
- **Problèmes de fournitures, d'équipements, de médicaments** : les fournitures ou l'équipement (médicaments) sont indisponibles ou non fonctionnels ou cassés
- **Problèmes de gestion** : les prestataires souhaitent être rémunérés pour remplir cette fonction, les prestataires sont encouragés à effectuer des procédures alternatives, ou sont mal à l'aise ou peu disposés à effectuer la procédure pour des raisons sans rapport avec la formation.
- **Problèmes de politique** : Le niveau requis de personnel n'est pas affecté à cette FOSA en nombre suffisant (ou pas du tout), ou les politiques nationales ou de la FOSA ne permettent pas l'exécution de la fonction.
- **Aucune indication** : Aucun client ayant besoin de ce service n'est venu à la FOSA pendant cette période.

Fonction de signalisation	**Effectué au cours des 3 derniers mois ?**	**Si Non effectué au cours des 3 derniers mois, pourquoi ?**
1. Des antibiotiques ont-ils été administrés par voie parentérale à une femme enceinte ou récemment accouchée au cours des 3 derniers mois ?	0 _____ Non 1 _____ Oui	1 ____Problèmes de formation 2 ____ Fournitures, équipement, problèmes de médicaments 3 ____ Problèmes de gestion 4 ____ Problèmes de politique 5 ____ Aucune indication
2. Des utéro toniques ont-ils été administrés par voie parentéraux au cours des 3 derniers mois ? (p. ex. ocytocine parentérale, ergométrine, misoprostol)	0 _____ Non 1 _____ Oui	1 ____Problèmes de formation 2 ____ Fournitures, équipement, problèmes de médicaments 3 ____ Problèmes de gestion 4 ____ Problèmes de politique 5 ____ Aucune indication
3. Des anticonvulsivants pour la prééclampsie sévère ou l'éclampsie ont-ils été administrés par voie parentérale au cours des 3 derniers mois ? (par exemple, sulfate de magnésium)	0 _____ Non 1 _____ Oui	1 ____Problèmes de formation 2 ____ Fournitures, équipement, problèmes de médicaments 3 ____ Problèmes de gestion 4 ____ Problèmes de politique 5 ____ Aucune indication
4. L'extraction manuelle du placenta a-t-elle été effectuée au cours des 3 derniers mois ?	0 _____ Non 1 _____ Oui	1 ____Problèmes de formation 2 ____ Fournitures, équipement, problèmes de médicaments 3 ____ Problèmes de gestion 4 ____ Problèmes de politique 5 ____ Aucune indication
5. L'extraction des débits intra-utérins a-t-elle été effectuée au cours des 3 derniers mois ? (par exemple, aspiration manuelle sous vide, dilatation et curetage)	0 _____ Non 1 _____ Oui	1 ____Problèmes de formation 2 ____ Fournitures, équipement, problèmes de médicaments 3 ____ Problèmes de gestion 4 ____ Problèmes de politique 5 ____ Aucune indication

6. Un accouchement par voie basse assisté (par exemple, extraction par ventouse, accouchement par forceps) a-t-il été pratiqué au cours des 3 derniers mois ?	0 _____ Non 1 _____ Oui	1 ____Problèmes de formation 2 ____ Fournitures, équipement, problèmes de médicaments 3 ____ Problèmes de gestion 4 ____ Problèmes de politique 5 ____ Aucune indication
7. Une réanimation néonatale avec ballon et masque a-t-elle été pratiquée au cours des 3 derniers mois ?	0 _____ Non 1 _____ Oui	1 ____Problèmes de formation 2 ____ Fournitures, équipement, problèmes de médicaments 3 ____ Problèmes de gestion 4 ____ Problèmes de politique 5 ____ Aucune indication
8. Une transfusion sanguine a-t-elle été effectuée au cours des 3 derniers mois ?	0 _____ Non 1 _____ Oui	1 ____Problèmes de formation 2 ____ Fournitures, équipement, problèmes de médicaments 3 ____ Problèmes de gestion 4 ____ Problèmes de politique 5 ____ Aucune indication
9. Une césarienne a-t-elle été pratiquée au cours des 3 derniers mois ?	0 _____ Non 1 _____ Oui	1 ____Problèmes de formation 2 ____ Fournitures, équipement, problèmes de médicaments 3 ____ Problèmes de gestion 4 ____ Problèmes de politique 5 ____ Aucune indication

V. PRESTATION DES SERVICES SONU

Je voudrais poser quelques questions supplémentaires sur la prestation de certains services SONU

QN	Question	Réponse(s)
501	Un ou plusieurs prestataires de services de maternité dans cette FOSA ont-ils reçu une formation en soins obstétricaux et néonatals d'urgence (SONUB/SONUC) ?	1. _____ [Oui] 2. _____ [Non] 3. _____ [Je ne sais pas, pas de réponse]
502	Si « Oui » à la question ci-dessus, combien de prestataires ont déjà reçu une formation SONU ?	1._____SONUB 2._____ SONUC
503	Un ou plusieurs prestataires de services de maternité dans cette FOSA ont-ils reçu une formation en soins obstétricaux et néonatals d'urgence (SONU) au cours des **deux dernières années** ?	1. _____ [Oui] 2. _____ [Non] 3. _____ [Je ne sais pas, pas de réponse]
504	Si « Oui » à la question ci-dessus, combien de prestataires ont reçu une formation en SONU au cours des deux dernières années ?	1._____SONUB 2._____ SONUC
505	Y a-t-il eu des interruptions dans la disponibilité de sang pour transfusion au cours des 3 derniers mois ?	1. _____ [Oui] 2. _____ [Non] 3. _____ [Je ne sais pas, pas de réponse]
506	Combien de réfrigérateurs pour le stockage du sang sont disponibles dans cette FOSA ?	_____

	Combien de réfrigérateurs pour le stockage du sang sont présentement fonctionnels dans cette FOSA ?	_____
507	Y a-t-il un endroit dans cette FOSA où l'on procède au dépistage sanguin des maladies infectieuses avant la transfusion ?	1. _____ [Oui] 2. _____ [Non] 3. _____ [Je ne sais pas, pas de réponse]
508	Combien de jours les femmes restent-elles généralement dans la FOSA après un accouchement normal ?	1. _____ 2. _____ [Je ne sais pas, pas de réponse]
509	Combien de jours en moyenne les femmes restent-elles dans la FOSA après l'accouchement par césarienne ?	1. _____ 2. _____ [Je ne sais pas, pas de réponse]
510	Des soins de mère kangourou pour les bébés prématurés/de très faible poids à la naissance sont-ils fournis dans cette FOSA?	1. _____ [Oui] 2. _____ [Non] 3. _____ [Je ne sais pas, pas de réponse]
511	Combien d'heures conseillez-vous aux mères de faire le contact peau à peau avec les bébés ?	_____ [heures]
512	Combien de fois par jour conseillez-vous aux mères d'avoir un contact peau à peau avec les bébés ?	_____
513	Existe-t-il un coin nouveau-né/une zone pour la réanimation des nouveau-nés dans la salle d'accouchement ?	1. _____ [Oui] 2. _____ [Non] 3. _____ [Je ne sais pas, pas de réponse]
514	Existe-t-il un coin nouveau-né/une zone pour la réanimation des nouveau-nés dans le bloc opératoire?	1. _____ [Oui] 2. _____ [Non] 3. _____ [Je ne sais pas, pas de réponse]
515	Avez-vous les directives nationales/protocole/manuels de formation pour les soins essentiels (SONE) à l'accouchement disponibles dans cette FOSA aujourd'hui ?	1. _____ [Oui] 2. _____ [Non] 3. _____ [Je ne sais pas, pas de réponse]
516	Avez-vous les directives nationales/protocole/modèle de formation pour les soins obstétricaux et néonatals d'urgence (SONU) disponibles dans cette FOSA aujourd'hui ?	1. _____ [Oui] 2. _____ [Non] 3. _____ [Je ne sais pas, pas de réponse]

VI. DONNEES DES REGISTRES DE LA FOSA

À partir des registres de la FOSA, veuillez fournir le nombre de cas pour chaque catégorie pour la période de 3 mois de janvier à mars 2022 et pour l'ensemble de 2021

QN	Question	Réponse(s)
601	Les césariennes d'urgence	1. _____ [T1 2021] 2. _____ [T2 2021] 3. _____ [T3 2021] 4. _____ [T4 2021] 5. _____ [T1 2022]
602	Nombre de baxters de sang transfusé (pour la maternité)	1. _____ [T1 2021] 2. _____ [T2 2021] 3. _____ [T3 2021] 4. _____ [T4 2021] 5. _____ [T1 2022]

603	Naissances vivantes	1. _____ [T1 2021] 2. _____ [T2 2021] 3. _____ [T3 2021] 4. _____ [T4 2021] 5. _____ [T1 2022]
604	Cas référés vers cette FOSA en raison de complications maternelles	1. _____ [T1 2021] 2. _____ [T2 2021] 3. _____ [T3 2021] 4. _____ [T4 2021] 5. _____ [T1 2022]
605	Cas référés vers cette FOSA en raison de complications néonatales	1. _____ [T1 2021] 2. _____ [T2 2021] 3. _____ [T3 2021] 4. _____ [T4 2021] 5. _____ [T1 2022]
606	Cas référés par cette FOSA raison des complications maternelles	1. _____ [T1 2021] 2. _____ [T2 2021] 3. _____ [T3 2021] 4. _____ [T4 2021] 5. _____ [T1 2022]
607	Cas référés par cette FOSA raison des complications néonatales	1. _____ [T1 2021] 2. _____ [T2 2021] 3. _____ [T3 2021] 4. _____ [T4 2021] 5. _____ [T1 2022]

VII. DISPONIBILITÉ DES ÉQUIPEMENTS, FOURNITURES ET MÉDICAMENTS SONU

Je voudrais poser quelques questions supplémentaires concernant l'équipement de soins obstétricaux et néonatals [disponibilité et fonctionnalité] et les fournitures dans le service de maternité ainsi que des questions sur la disponibilité des médicaments.

POUR L'ÉQUIPEMENT, demander s'il est disponible ET fonctionnel.

QN	Question	Réponse(s)
701	Lampe d'examen (une lampe de poche fonctionnelle est acceptable)	1. _____ [Oui] 2. _____ [Non] 3. _____ [Disponible mais PAS fonctionnel] 4. _____ [Je ne sais pas, pas de réponse]
702	Kit de maternité disponible et fonctionnel	1. serre-cordon, 2. ciseaux à épisiotomie 3. ciseaux/lame pour couper le cordon 4. matériel de suture avec aiguille 5. porte-aiguille 6. 2 champs stériles 70 X 70 7. 2 x 5 compresses stériles 7,5 x 7,5 8. 2 paires de gants stériles 9. 2 masques 3 plis 10. 2 casaques 11. 1 canule de Guède nouveau-né T 000 stérile

		12. 1 sonde d'aspiration pédiatrique stérile CH 6 13. 1 raccord biconique 14. 2 clamps ombilicaux stériles 15. 2 désinfectants gynécologiques 16. 1 bonnet 17. 1 drap isothermique stérile 18. 1 masque d'inhalation O2 adulte haute concentration 19. 1 masque d'inhalation O2 pédiatrique très haute concentration 20. 1 paire de ciseaux stériles
703	Appareil d'aspiration (bulbe d'aspiration ou pompe d'aspiration électrique)	1. _____ [Oui] 2. _____ [Non] 3. _____ [Disponible mais PAS fonctionnel] 4. _____ [Je ne sais pas, pas de réponse]
704	Ballon et masque de réanimation - adulte	1. _____ [Oui] 2. _____ [Non] 3. _____ [Disponible mais PAS fonctionnel] 4. _____ [Je ne sais pas, pas de réponse]
705	Sac néonatal et masque taille 1- pour bébés nés à terme	1. _____ [Oui] 2. _____ [Non] 3. _____ [Disponible mais PAS fonctionnel] 4. _____ [Je ne sais pas, pas de réponse]
706	Sac néonatal et masque taille 0- pour les bébés prématurés	1. _____ [Oui] 2. _____ [Non] 3. _____ [Disponible mais PAS fonctionnel] 4. _____ [Je ne sais pas, pas de réponse]
707	Table de réanimation avec source de chaleur pour la réanimation du nouveau-né	1. _____ [Oui] 2. _____ [Non] 3. _____ [Disponible mais PAS fonctionnel] 4. _____ [Je ne sais pas, pas de réponse]
708	Partogramme vierge	1. _____ [Oui] 2. _____ [Non] 3. _____ [Disponible mais PAS fonctionnel] 4. _____ [Je ne sais pas, pas de réponse]
709	Gants stériles	1. _____ [Oui] 2. _____ [Non] 3. _____ [Disponible mais PAS fonctionnel] 4. _____ [Je ne sais pas, pas de réponse]
710	Pèse-bébé dans la salle d'accouchement	1. _____ [Oui] 2. _____ [Non] 3. _____ [Disponible mais PAS fonctionnel] 4. _____ [Je ne sais pas, pas de réponse]
711	Appareil de mesure de la tension artérielle dans la salle d'accouchement	1. _____ [Oui] 2. _____ [Non] 3. _____ [Disponible mais PAS fonctionnel] 4. _____ [Je ne sais pas, pas de réponse]
712	Oxymètre de pouls - adulte	1. _____ [Oui]

		2. _____ [Non] 3. _____ [Disponible mais PAS fonctionnel] 4. _____ [Je ne sais pas, pas de réponse]
713	Oxymètre de pouls - pédiatrique	1. _____ [Oui] 2. _____ [Non] 3. _____ [Disponible mais PAS fonctionnel] 4. _____ [Je ne sais pas, pas de réponse]
714	Oxymètre de pouls - néonatal	1. _____ [Oui] 2. _____ [Non] 3. _____ [Disponible mais PAS fonctionnel] 4. _____ [Je ne sais pas, pas de réponse]
715	Unité de photothérapie	1. _____ [Oui] 2. _____ [Non] 3. _____ [Disponible mais PAS fonctionnel] 4. _____ [Je ne sais pas, pas de réponse]
716	Oxygène (fourni par une bouteille, à partir d'une alimentation centrale ou par des concentrateurs d'oxygène)	1. _____ [Oui] 2. _____ [Non] 3. _____ [Disponible mais PAS fonctionnel] 4. _____ [Je ne sais pas, pas de réponse]
717	Table d'opération	1. _____ [Oui] 2. _____ [Non] 3. _____ [Disponible mais PAS fonctionnel] 4. _____ [Je ne sais pas, pas de réponse]
718	Machine d'anesthésie pour délivrer des gaz esthétiques et de l'oxygène	1. _____ [Oui] 2. _____ [Non] 3. _____ [Disponible mais PAS fonctionnel] 4. _____ [Je ne sais pas, pas de réponse]
719	Kit d'intubation - adulte (complet avec canule oropharyngée, sondes endotrachéales, laryngoscope, pince de Magill, stylet)	1. _____ [Oui] 2. _____ [Non] 3. _____ [Disponible mais PAS fonctionnel] 4. _____ [Je ne sais pas, pas de réponse]
720	Kit d'intubation - pédiatrique (complet avec canule oropharyngée, sondes endotrachéales, laryngoscope, pince de Magill, stylet)	1. _____ [Oui] 2. _____ [Non] 3. _____ [Disponible mais PAS fonctionnel] 4. _____ [Je ne sais pas, pas de réponse]
721	Aiguille à ponction lombaire	1. _____ [Oui] 2. _____ [Non] 3. _____ [Disponible mais PAS fonctionnel] 4. _____ [Je ne sais pas, pas de réponse]
722	Ventouse / forceps	1. _____ [Oui] 2. _____ [Non] 3. _____ [Disponible mais PAS fonctionnel] 4. _____ [Je ne sais pas, pas de réponse]
723	Appareil de monitoring fœtal	1. _____ [Oui] 2. _____ [Non] 3. _____ [Disponible mais PAS fonctionnel]

		4. _____ [Je ne sais pas, pas de réponse]
724	Echographe	1. _____ [Oui] 2. _____ [Non] 3. _____ [Disponible mais PAS fonctionnel] 4. _____ [Je ne sais pas, pas de réponse]
725	Chlorure de sodium (solution saline) (solution injectable)	1. _____ [Oui] 2. _____ [Non] 3. _____ [Disponible mais PAS fonctionnel] 4. _____ [Je ne sais pas, pas de réponse]
726	Azithromycine (cap/comprimé ou liquide oral)	1. _____ [Oui] 2. _____ [Non] 3. _____ [Disponible mais PAS fonctionnel] 4. _____ [Je ne sais pas, pas de réponse]
727	Céfixime (cap/tab)	1. _____ [Oui] 2. _____ [Non] 3. _____ [Disponible mais PAS fonctionnel] 4. _____ [Je ne sais pas, pas de réponse]
728	Poudre de benzathine benzylpénicilline (pour injection)	1. _____ [Oui] 2. _____ [Non] 3. _____ [Disponible mais PAS fonctionnel] 4. _____ [Je ne sais pas, pas de réponse]
729	Bétaméthasone ou Dexaméthasone (injectable)	1. _____ [Oui] 2. _____ [Non] 3. _____ [Disponible mais PAS fonctionnel] 4. _____ [Je ne sais pas, pas de réponse]
730	Nifédipine (cap/tab)	1. _____ [Oui] 2. _____ [Non] 3. _____ [Disponible mais PAS fonctionnel] 4. _____ [Je ne sais pas, pas de réponse]
731	Sulfate de magnésium	1. _____ [Oui] 2. _____ [Non] 3. _____ [Disponible mais PAS fonctionnel] 4. _____ [Je ne sais pas, pas de réponse]
732	Misoprotole	1. _____ [Oui] 2. _____ [Non] 3. _____ [Disponible mais PAS fonctionnel] 4. _____ [Je ne sais pas, pas de réponse]
733	Ampicilline	1. _____ [Oui] 2. _____ [Non] 3. _____ [Disponible mais PAS fonctionnel] 4. _____ [Je ne sais pas, pas de réponse]
734	Gentamycine	1. _____ [Oui] 2. _____ [Non] 3. _____ [Disponible mais PAS fonctionnel] 4. _____ [Je ne sais pas, pas de réponse]
735	Métronidazole	1. _____ [Oui]

		2. _____ [Non] 3. _____ [Disponible mais PAS fonctionnel] 4. _____ [Je ne sais pas, pas de réponse]
736	Gluconate de calcium	1. _____ [Oui] 2. _____ [Non] 3. _____ [Disponible mais PAS fonctionnel] 4. _____ [Je ne sais pas, pas de réponse]
737	Hydralazine	1. _____ [Oui] 2. _____ [Non] 3. _____ [Disponible mais PAS fonctionnel] 4. _____ [Je ne sais pas, pas de réponse]
738	Ocytocine	1. _____ [Oui] 2. _____ [Non] 3. _____ [Disponible mais PAS fonctionnel] 4. _____ [Je ne sais pas, pas de réponse]
739	Pommade oculaire antibiotique pour nouveau-né	1. _____ [Oui] 2. _____ [Non] 3. _____ [Disponible mais PAS fonctionnel] 4. _____ [Je ne sais pas, pas de réponse]

Qualité des SOINS

Ces données proviennent des dossiers de maternité/bloc opératoire/néonatologie/pédiatrie

Dossiers maternité						
Paramètre (indicateur) de qualité des soins	Mars 2022		Avril 2022		Mai 2022	
	Total de femmes admises	Nbre de femmes ayant reçu le service	Total de femmes admises	Nbre de femmes ayant reçu le service	Total de femmes admises	Nbre de femmes ayant reçu le service
Prise de tension artérielle à l'admission						
Prise de pouls à l'admission						
Prise de température à l'admission						
Prise des BCF a l'admission						
Surveiller le saignement au cours des 2h en postpartum						
Prise de pouls au cours des 2h en postpartum						
Prise de température au cours des 2h en postpartum						
Prise de tension artérielle au cours des 2h en postpartum						
Administration d'un utero tonique après accouchement						
Nouveau-nés	**Total**	**Pesés**	**Total**	**Pesés**	**Total**	**Pesés**
Nombre des nouveau-nés pesés par mois						

Supplemental material 8. Individual mother questionnaire

Note : Lire le consentement en Kirundi et poser les questions en Kirundi

Questionnaire individuel femme (après accouchement, vaccination, CPON, nutrition du nouveau-né)		
I. IDENTIFICATION DE L'ETABLISSEMENT DE SANTE		
QN	**Question**	**Réponse**
101	Nom de l'établissement de santé	_____
102	Type de l'établissement de santé	1. _____ [Centre de santé] 2. _____ [Hôpital de District] 3. _____ [Hôpital régional] 4. _____ [Hôpital national]
	Est-ce que cette FOSA a été transformée comme Hôpital communal ?	1. _____ [Oui] 2. _____ [Non]
103	Nom du District sanitaire	_____
104	Type de résidence (lieu)	1. _____ [urbain] 2. _____ [rural]
105	Statut de la FOSA	1. _____ [Publique] 2. _____ [confessionnelle] 3. _____ [privée] 4. _____ [autre, à préciser]
II. QUESTIONS FEMME		
2.1	Est-ce que vous avez le carnet sante mère-enfant ?	1. Oui __ 2. Non____
2.2	Si oui, savez-vous l'importance de ce carnet ?	1. Oui __ 2. Non____
2.3	Si oui, lesquels ?	1. Suivi de la grossesse et du nouveau-né 2. Facilite l'enregistrement des naissances
2.4	Êtes-vous satisfaite de l'accueil qu'on vous a réservée au cours de votre visite en maternité	1. Très satisfaite__ 2. Satisfaite____ 3. Insatisfaite____ 4. Pas du tout satisfaite____ 5. Pas de réponse____
2.5	Pensez-vous avoir été suffisamment informée par le personnel soignant sur votre prise en charge ?	1. Très satisfaite__ 2. Satisfaite____ 3. Insatisfaite____ 4. Pas du tout satisfaite____ 5. Pas de réponse____
2.6	Êtes-vous satisfaite des soins qu'on vous a donnés au cours de votre séjour en maternité ?	1. Très satisfaite__ 2. Satisfaite____ 3. Insatisfaite____ 4. Pas du tout satisfaite____ 5. Pas de réponse____
2.7	Pensez-vous que le personnel soignant vous a donné la chance de discuter sur votre santé et auriez-vous eu l'opportunité de lui poser des	1. Très satisfaite__ 2. Satisfaite____ 3. Insatisfaite____ 4. Pas du tout satisfaite____

	questions concernant votre santé et prise en charge ?	5. Pas de réponse_____
2.8	Pensez-vous que le personnel soignant, en plus des soins reçus, vous a bien traitée (soins humanisés 'kuremesha') et encouragée pendant votre séjour en maternité	1. Très satisfaite__ 2. Satisfaite____ 3. Insatisfaite____ 4. Pas du tout satisfaite____ 5. Pas de réponse____
2.9	Est-ce que quelqu'un vous a demandé de lui donner un don ou de l'argent comme récompense durant votre séjour en maternité ?	1. Oui__ 2. Non____
2.10	Avez-vous été demandé de payer (secrètement ou pas) de l'argent durant votre séjour en maternité ('gupfumbatisha')	1. Oui__ 2. Non____
2.11	Avez-vous reçu un counseling après l'accouchement ?	1. Oui__ 2. Non____
2.12	Si oui, sur lesquels des aspects suivants ?	1. Planning familial__ 2. Allaitement exclusif____ 3. VIH_____ 4. Les signes de danger maternel en postpartum___ 5. Les signes de danger du nouveau-né_____ 6. Vaccination du nouveau-né___ 7. Les dates des CPON___
2.13	Avez-vous reçu un contraceptif de votre choix avant la sortie de la maternité ?	1. Oui__ 2. Non____
2.14	Est-ce le personnel soignant a posé votre bébé au niveau de la poitrine juste avec l'accouchement ?	1. Oui__ 2. Non____
2.15	Avez-vous donné du sein à votre bébé dans la première heure après l'accouchement ?	1. Oui__ 2. Non____
2.16	Avez-vous été informée qu'il faut attendre au moins un jour avant de laver votre nouveau-né ?	1. Oui__ 2. Non____
2.17	A votre arrivée, vous vous êtes dirigée ou ?	1. Maternite 2. CPN 3. Urgence 4. Consultation externe 5. Autre a préciser
2.18	Si pas dans le service de maternité, combien de temps (minutes) en moyenne avez-vous passée dans ce service ?	……..……
2.19	Arrivée dans le service de maternité, après combien de temps en minutes avez-vous été accueilli/reçue ?	…….

Supplemental material 9. EmONC competence assessment tool

Interviewee ID : _____ |_____ [two numerical digits plus two alphabetical digits]

Code de l'évaluateur : _____ |_____ [deux chiffres numériques plus deux chiffres alphabétiques]

Date de la collecte : _____ |_____ |_____ [Jour | Mois |Année]

ID de l'enquêté : _____ |_____ [deux chiffres numériques plus deux chiffres alphabétiques]

I. IDENTIFICATION DE L'ETABLISSEMENT DE SANTE		
QN	**Question**	**Réponse**
101	Nom de l'établissement de santé	_____
102	Type de l'établissement de santé	1. _____ [Centre de santé] 2. _____ [Hôpital de District] 3. _____ [Hôpital régional] 4. _____ [Hôpital national]
103	Est-ce que cette FOSA a été transformée comme Hôpital communal ?	1. _____ [Oui] 2. _____ [Non]
104	Nom du District sanitaire	_____
105	Type de résidence (lieu)	1. _____ [urbain] 2. _____ [rural]
106	Statut de la FOSA	1. _____ [Publique] 2. _____ [confessionnelle] 3. _____ [privée] 4. _____ [autre, à préciser]
II. QUESTIONNAIRE DU PRESTATAIRE		
QN	**Question**	**Réponse(s)**
201	Dans laquelle de ces services travaillez-vous actuellement ?	1. ___ [service de maternité uniquement] 2. ___ [CPN, accouchement, CPON] 3. ___ [CPN, accouchement, CPON, vaccination] 4. ___ [tous les services y compris les urgences, etc.]
SECTION 1. DONNES SOCIO-DEMOGRAPHIQUES		
210	Quel est votre sexe ?	1. ___ [féminin] 2. ___ [masculin]
211	Quel âge as-tu à années ?	_____ [année]
212	Quelle est votre qualification professionnelle actuelle ?	1. ___ [Obstétricien/Gynécologue] 2. ___ [Médecin] 3. ___ [Sage-femme] 4. ___ [Infirmier A0] 5. ___ [Infirmier A1] 6. ___ [Infirmier A2] 7. ___ [Infirmier A3]

213	Combien d'années d'expérience avez-vous depuis que vous avez terminé votre qualification professionnelle actuelle ?	_____ années _____ Mois
214	Depuis combien de temps travaillez-vous dans cette FOSA ?	_____ années _____ Mois
215	Depuis combien de temps travaillez-vous dans cette fonction au sein de cette FOSA	_____ années _____ Mois
216	Travaillez-vous actuellement à temps plein ou à temps partiel dans cette FOSA ?	1. ___ [Temps plein] 2. ___ [Temps partiel]
217	Combien d'accouchements par voie basse avez-vous dirigés en au cours des 3 derniers mois ?	_____
218	Combien de césariennes avez-vous effectuées en tant que prestataire principal (chirurgien principal) au cours des 3 derniers mois ?	_____
219	Avez-vous déjà suivi une formation continue en santé maternelle et néonatale depuis que vous êtes en activité ?	1. ___ [Oui] 2. ___ [Non]
2111	Si oui, lequel des éléments suivants avez-vous reçu en tant que formation continue ?	1. ____ [SONUB] 2. ____ [SONUC] 3. ____ [SONE] 4. ____[planification familiale] 5. ____[Réalisation de la transfusion sanguine] 6. ____ [Soins prénatals recentrés]
2112	Laquelle de ces formations est récente (une seule réponse)	1. ____ [SONUB] 2. ____ [SONUC] 3. ____ [SONE] 4. ____[planification familiale] 5. ____[Réalisation de la transfusion sanguine] 6. ____ [Soins prénatals recentrés]
2113	De quand date ta formation récente (Année)	_____ [année] ____ [mois]

SECTION 2. PERCEPTIONS SUR LES CONDITIONS DE TRAVAIL, LA QUALITÉ DES SOINS ET LA CONFIANCE EN SOI

Veuillez indiquer dans quelle mesure vous acceptez que les éléments suivants sont présents dans le service ou vous travaillez.

Section 2a. Perception des prestataires de soins sur les conditions de travail dans la formation sanitaire

221	En général, je suis satisfait de ce travail	1. ___ [Fortement en désaccord] 2. ___ [Plutôt en désaccord] 3. ___ [Plutôt d'accord] 4. ___ [Tout à fait d'accord]
222	Il y a une supervision clinique adéquate dans ce poste	1. ___ [Fortement en désaccord] 2. ___ [Plutôt en désaccord] 3. ___ [Plutôt d'accord] 4. ___ [Tout à fait d'accord]
223	Je sens que ma charge de travail est gérable	1. ___ [Fortement en désaccord] 2. ___ [Plutôt en désaccord] 3. ___ [Plutôt d'accord] 4. ___ [Tout à fait d'accord]

224	Si cela ne tenait qu'à moi, je continuerais à travailler pour cette FOSA	1. ___ [Fortement en désaccord] 2. ___ [Plutôt en désaccord] 3. ___ [Plutôt d'accord] 4. ___ [Tout à fait d'accord]
Section 2b. Perceptions des prestataires de soins sur la qualité des soins dans leur établissement Veuillez réfléchir à la qualité globale des soins maternels et néonatals de la FOSA et sélectionner la déclaration qui reflète votre opinion		
225	La qualité des soins prénatals (CPN) que nous fournissons dans cette FOSA est en général	1. ___ [Pauvre] 2. ___ [Juste] 3. ___ [Bien] 4. ___ [Excellent]
226	La qualité des soins d'accouchement que nous offrons dans cette FOSA est en général	1. ___ [Pauvre] 2. ___ [Juste] 3. ___ [Bien] 4. ___ [Excellent]
227	La qualité des soins aux nouveau-nés que nous offrons dans cette FOSA est en général	1. ___ [Pauvre] 2. ___ [Juste] 3. ___ [Bien] 4. ___ [Excellent]
228	Le niveau de respect que nous accordons aux femmes en travail et pendant l'accouchement dans cette FOSA est en général	1. ___ [Pauvre] 2. ___ [Juste] 3. ___ [Bien] 4. ___ [Excellent]
229	La qualité des soins postnatals (CPON) que nous offrons dans cette FOSA est en général	1. ___ [Pauvre] 2. ___ [Juste] 3. ___ [Bien] 4. ___ [Excellent]
Section 2c. Préférence du prestataire de soins pour le lieu d'accouchement Veuillez réfléchir à la qualité globale des soins de la FOSA pour le travail et l'accouchement et sélectionner la déclaration qui reflète votre opinion.		
2210	Recommanderiez-vous cette FOSA à un ami proche ou à un membre de votre famille pour l'accouchement ?	1. ___ [Fortement en désaccord] 2. ___ [Plutôt en désaccord] 3. ___ [Plutôt d'accord] 4. ___ [Tout à fait d'accord]
2211	Quelle est la principale raison pour laquelle vous voudriez que votre ami proche ou un membre de votre famille n'accouche pas dans cette FOSA?	1.___ Longue distance jusqu'au domicile 2.___ Coût élevé des soins 3.___ Faible approvisionnement en médicaments et matériel 4.___ Manque de prestataires de soins de santé amicaux 5.___ Mauvaise qualité pour les accouchements par voie basse 6.___ Incapable de traiter les complications si elles surviennent 9.___ Autre, précisez
SECTION 3. EVALUATION DES COMPETENCES CLINIQUES DU PESTATAIRE Pour chacun des éléments suivants, indiquez si vous avez géré ce cas au cours des **douze derniers mois**. Veuillez également indiquer votre propre confiance dans la qualité de vos compétences dans ce domaine		

2212	Avez-vous géré une prééclampsie ou une éclampsie sévère au cours des 12 derniers mois ?	1. ___ [Oui] 2. ___ [Non]
2213	En moyenne, combien de cas de prééclampsie sévère ou d'éclampsie avez-vous géré au cours des 12 derniers mois ?	_____
2214	Veuillez indiquer votre niveau de confiance dans la qualité de vos compétences dans la gestion de la prééclampsie sévère et de l'éclampsie	1. ___ [Très confiant] 2. ___ [Pas très confiant] 3. ___ [Je ne peux pas m'apprécier] 4. ___ [Ne s'applique pas]
2215	Avez-vous pris en charge une hémorragie post-partum au cours des 12 derniers mois ?	1. ___ [Oui] 2. ___ [Non]
2216	En moyenne, combien de cas d'hémorragie du post-partum avez-vous pris en charge au cours des 12 derniers mois ?	_____
2217	Veuillez indiquer votre niveau de confiance dans la qualité de vos compétences dans la prise en charge de l'hémorragie post-partum	1. ___ [Très confiant] 2. ___ [Pas très confiant] 3. ___ [Je ne peux pas m'apprécier] 4. ___ [Ne s'applique pas]
2218	Avez-vous géré un travail dystocique au cours des 12 derniers mois ?	1. ___ [Oui] 2. ___ [Non]
2219	Combien, combien de cas de dystocie avez-vous géré au cours des 12 derniers mois ?	_____
2220	Veuillez indiquer votre niveau de confiance dans la qualité de vos compétences dans la gestion du travail dystocique	1. ___ [Très confiant] 2. ___ [Pas très confiant] 3. ___ [Je ne peux pas m'apprécier] 4. ___ [Ne s'applique pas]
2221	Avez-vous réussi à accoucher par le siège au cours des 12 derniers mois ?	1. ___ [Oui] 2. ___ [Non]
2222	En moyenne, combien de cas d'accouchement par le siège avez-vous géré au cours des 12 derniers mois ?	_____
2223	Veuillez indiquer votre niveau de confiance dans la qualité de vos compétences dans la gestion de l'accouchement par le siège	1. ___ [Très confiant] 2. ___ [Pas très confiant] 3. ___ [Je ne peux pas m'apprécier] 4. ___ [Ne s'applique pas]
2224	Avez-vous pratiqué la réanimation d'un nouveau-né à l'aide d'un ballon et d'un masque au cours des 12 derniers mois ?	1. ___ [Oui] 2. ___ [Non]
2225	En moyenne, combien de réanimations néonatales avec ballon et masque avez-vous réalisées au cours des 12 derniers mois ?	_____
2226	Veuillez indiquer votre niveau de confiance dans la qualité de vos compétences en matière de réanimation néonatale à l'aide d'un ballon et d'un masque	1. ___ [Très confiant] 2. ___ [Pas très confiant] 3. ___ [Je ne peux pas m'apprécier] 4. ___ [Ne s'applique pas]
2227	Avez-vous géré le paludisme pendant la grossesse au cours des 12 derniers mois ?	1. ___ [Oui] 2. ___ [Non]
2228	En moyenne, combien de cas de paludisme pendant la grossesse avez-vous géré au cours des 12 derniers mois ?	_____

2229	Veuillez indiquer votre niveau de confiance dans la qualité de vos compétences dans la gestion du paludisme pendant la grossesse	1. ___ [Très confiant] 2. ___ [Pas très confiant] 3. ___ [Je ne peux pas m'apprécier] 4. ___ [Ne s'applique pas]
2230	Avez-vous géré l'hypertension pendant la grossesse au cours des 12 derniers mois ?	1. ___ [Oui] 2. ___ [Non]
2231	En moyenne, combien de cas d'hypertension pendant la grossesse avez-vous géré au cours des 12 derniers mois ?	_____
2232	Veuillez indiquer votre niveau de confiance dans la qualité de vos compétences dans la gestion de l'hypertension pendant la grossesse	1. ___ [Très confiant] 2. ___ [Pas très confiant] 3. ___ [Je ne peux pas m'apprécier] 4. ___ [Ne s'applique pas]
	Comment reconnaissez-vous qu'une complication nécessite une compétente au-delà du paquet disponible dans votre FOSA?	_____

SECTION 4. EVALUATION DES CONNAISSANCES SUR LES SOINS MATERNELS ET NÉONATALS

Cette section comporte une évaluation générale des connaissances. Il ne s'agit PAS d'un examen et vos réponses ne seront PAS liées à votre identité. Vos réponses n'auront PAS D'INCIDENCE sur votre statut d'emploi auprès de cette FOSA.

Informations générales

K1	Code de la FOSA :	Date et heure de l'administration du questionnaire :
K2	Votre qualification ? Cocher la réponse appropriée ✓	⌋ 1. Obstétricien/Gynécologue ⌋ 2. Résident ⌋ 3. Médecin généraliste ⌋ 4. Sage-femme ⌋ 5. Infirmier licencié ⌋ 6. Infirmier ⌋ 7. Autre (spécifier):
K3	Sexe du prestataire	⌋ Masculin ⌋ Féminin

Pour les questions suivantes, ne pas lire les options, plutôt cocher les réponses spontanées et demander des précisions

K4	La dernière fois que vous avez dirigé un accouchement ? Cocher la réponse spontanée ✓	⌋ 1. Il y'a quelques jours (<6 jours) ⌋ 2. Dans les semaines passées (<1mois) ⌋ 3. Les mois passés (<6mois) ⌋ 4. Il y'a plus de six mois ⌋ 5. Autre (spécifier):

K5	Pour une femme en travail, Quelles sont les éléments de suivi que vous effectuez normalement ? Cocher les réponses spontanées (Autoriser les réponses multiples)	1. Surveiller les BCF 2. Évaluer le degré de modelage du crâne fœtal 3. Évaluer la dilatation du col 4. Évaluer la descente de la tête 5. Surveiller les contractions utérines 6. Surveiller la tension artérielle de la mère 7. Surveiller le rythme respiratoire de la mère 8. Surveiller la température de la mère 9. Surveiller le pouls de la mère 10. Contrôler les urines 11.Autre (préciser) :	Mesures essentielles Si les variables 1, 2, 3, 4, 5, 6, 7, 8, 9, et 10 sont toutes mentionnées, inscrire 1 dans la case qui suit. Inscrire 0 si moins que les 10 variables essentielles sont mentionnées. ⌋

Prevention des Infections			
K6	Pour diriger un accouchement, quelles sont les précautions de prévention des infections à entreprendre ? Cocher les réponses spontanées ✓ (Autoriser les réponses multiples)	⌋ 1. Mettre un tablier en plastique, des bottes et des lunettes ⌋ 2. Lavage des mains avec savon antiseptique, et séchage avec linge propre ⌋ 3. Porter les gans stériles ⌋ 4. Nettoyer le périnée avec compresse imbibée de solution antiseptique, avec un mouvement d'avant en arrière ⌋ 5. Placer sous les fesses de la parturiente un des champs stériles, un autre couvre l'abdomen et le troisième est utilisé pour accueillir le nouveau-né ⌋ 6. Autres : (spécifier)	Si les variables 1, 2, 3, 4, et 5 sont toutes mentionnées, inscrire 1 dans la case qui suit. Inscrire 0 si moins que les 5 variables essentielles sont mentionnées.
K7	Quels sont les signes du danger à rechercher si une femme enceinte consulte avec suspicion de paludisme sévère ? Cocher les réponses spontanées ✓ (Autoriser les réponses multiples)	⌋ 1. Fièvre (au-delà 38°C) ⌋ 2. Confusion/Coma ⌋ 3. Pâleur ⌋ 4. Ictère (Yeux jaunâtres) ⌋ 5. État du fœtus ⌋ 6. Vertiges ⌋ 7. Douleurs articulaires ⌋ 8. Déshydratation ⌋ 8. Autres : (spécifier)	Si les variables : 1, 2, 3, 4, 5, 6, et 7 sont toutes mentionnées inscrire 1 dans la case Inscrire 0 si moins que les 7variables essentielles sont mentionnées.
K8	Quand une femme arrive en CPN avec des symptômes de paludisme sévère, quelle est votre conduite immédiate ? Cocher les réponses spontanées ✓ (Autoriser les réponses multiples)	1. Procéder immédiatement à l'admission 2.Amorcer le tableau des signes vitaux 3. Quinine et dextrose en IV 4. Lamelle de sang pour MPS 5. Contrôler l'hémoglobine 6. Autre : (préciser)	Si les variables : 1, 2, 3, 4, 5 sont toutes mentionnées inscrire 1 dans la case Inscrire 0 si moins que les 5 variables essentielles sont mentionnées.
K9	Quelles mesures prendriez-vous en matière de PTME pendant le travail et l'accouchement ?	1.Administrer de la NVP au début du travail si la patiente est séropositive au VIH 2. Offrir un test de dépistage si le statut sérique est inconnu 3.Administrer de la NVP au nourrisson	Si les variables 1, 2 et 3 sont toutes trois mentionnées, inscrire 1 dans la case qui suit. Inscrire 0 si on a mentionné moins que les trois
Gestion de l'hémorragie			
K10	Si une femme se présente et a une hémorragie importante ou fait une hémorragie après l'accouchement, quels signes recherchez-vous ? Cocher les réponses spontanées (Autoriser les réponses multiples) (Chercher à savoir s'il y a autre chose.)	1. Utérus non contracté 2. Signes de choc (étourdissements, tension artérielle basse) 3. Importance du saignement externe 4. Rétention des suites/du placenta 5.Vérifier si la vessie est pleine 6. Lésions du canal génital 7. Signes d'anémie 8.Autre (préciser):	Signes essentiels Si les variables 1,2, 3, 4, 5, 6 et 7 sont toutes mentionnées, inscrire 1 dans la case. Inscrire 0 si on mentionne moins que les cinq signes essentiels. ⌋

K11	Si une femme se présente et a une hémorragie importante ou fait une hémorragie après l'accouchement, quelles mesures prenez-vous ? Cocher les réponses spontanées (Autoriser les réponses multiples) (Demander s'il y a autre chose)	1. Massage du fond de l'utérus 2.Vider la vessie de la patiente 3. Donner de l'ergométrie IM ou IV (ocytocine) 4. Commencer les liquides par intraveineuse 5. Prélever du sang pour l'hémoglobine et l'épreuve de compatibilité croisée 6.Vérifier s'il y a des déchirures 7. Extraction manuelle des suites 8.Aiguiller en consultation 9. Relever le pied du lit 10.Autre (préciser) :	Mesures essentielles Si les variables 1, 2, 3, 4, 5, 6, 7, 8, et 9 sont toutes mentionnées, inscrire 1 dans la case. Inscrire 0 si on mentionne moins que les quatre mesures essentielles.
K12	Indications et principales étapes de la GATPA (Gestion Active de la Troisième Phase d'Accouchement) ? Cocher les réponses spontanées (Autoriser les réponses multiples) (Demander s'il y a autre chose)	⌋ 1. Tous les accouchés ⌋ 2. Injection de l'ocytocine ⌋ 3. Traction contrôlée du cordon ⌋ 4. Massage utérin après sortie du placenta pour maintenir l'utérus tonique ⌋ 5. Examen de routine du placenta et des membranes ⌋ 6. Examen de routine du vagin et périnée pour des déchirures éventuels ⌋ 7. Autres (préciser):	Mesures essentielles Si les variables 1, 2, 3, 4, 5 et 6 sont toutes mentionnées, inscrire 1 dans la case. Inscrire 0 si on mentionne moins que les 6 mesures essentielles.
K13	La femme que vous venez d'accoucher fait une rétention du placenta ; que faites-vous ? Cocher les réponses spontanées (Autoriser les réponses multiples) (Demander s'il y a autre chose)	1.Vider la vessie 2.Appliquer une traction contrôlée sur le cordon 3. Répéter l'ocytocine 4. Procéder à l'extraction manuelle du placenta 5. Donner des liquides par IV 6. Prendre les signes vitaux pour dépister un choc et agir 7. S'assurer que l'utérus est bien contracté 8. Déterminer le groupe sanguin et la compatibilité croisée 9. Préparer pour l'opération 10.Aiguiller en consultation 11.Autre (préciser) :	Mesures essentielles Si les variables 1, 2, 3, 4, 5, 6, 7, 8, 9 sont toutes mentionnées, inscrire 1 dans la case. Inscrire 0 si on mentionne moins que les quatre mesures essentielles.
K14	Si une femme se présente souffrant de malaise général 48 heures après l'accouchement, quels signes recherchez-vous ? Cocher les réponses multiples spontanées (Demander s'il y a autre chose)	1. Pouls élevé 2. Fièvre élevée 3. Choc septique (pouls indécelable) 4. Utérus sensible sous-involuté 5. Lochies dégageant une mauvaise odeur 6.Abdomen sensible 7. Autres: (spécifier)	Signes essentiels Si les variables 1, 2, 3, 4, 5 et 6 sont toutes mentionnées, inscrire 1 dans la case. Inscrire 0 si on mentionne moins que les 6 signes essentiels.

K15	Si une femme présente des complications résultant d'un avortement incomplet ou non sécuritaire, que faites-vous ? Cocher les réponses spontanées (Autoriser les réponses multiples) (Demander s'il y a autre chose)	1. Évaluer l'écoulement sanguin (Quantité du saignement vaginal) 2. Évaluer les signes vitaux 3.Amorcer l'irrigation par IV 4.Amorcer les antibiotiques 5. Procéder à une AMIU (aspiration manuelle intra-utérine) 6. Procéder à un examen vaginal 7. Faire une dilatation-curetage classique 8. Fournir du counseling 9.Aiguiller en consultation 10. Autres : (spécifier)	Mesures essentielles Si les variables 1, 2, 3, 4 et 5 sont toutes mentionnées, inscrire 1 dans la case. Inscrire 0 si on a mentionné moins que les cinq mesures essentielles.
Pre-éclampsie/éclampsie management			
K16	Femme de 24 ans se présente à la maternité avec des céphalées intenses et une douleur abdominale, Quelle est votre conduite ? Cocher les réponses spontanées (Autoriser les réponses multiples) (Demander s'il y a autre chose)	⌋ 1. Vérifier le terme de la grossesse ⌋ 2. Prendre les paramètres vitaux (Plus particulièrement la température et la TA) ⌋ 3. Caractériser la douleur abdominale (douleur épigastrique…) ⌋ 4. Chercher s'il y'a des troubles visuels associés (flou visuel) ⌋ 5. Autres (spécifier):	Mesures essentielles Si les variables 1, 2, 3, et 4 sont toutes mentionnées, inscrire 1 dans la case. Inscrire 0 si on a mentionné moins que les 4 mesures essentielles.
K17	Vous suspectez la prééclampsie sévère, Principaux signes positifs à rechercher ? Cocher les réponses spontanées (Autoriser les réponses multiples) (Demander s'il y a autre chose)	⌋ 1. Chiffres tensionnels élevés (diastole > 100mmhg) ⌋ 2. Céphalées intenses ⌋ 3. Flou visuel ⌋ 4. Douleur épigastrique ⌋ 5. Protéinurie (3+) ⌋ 6. Autre (spécifier):	Mesures essentielles Si les variables 1, 2, 3,4, et 5 sont toutes mentionnées, inscrire 1 dans la case. Inscrire 0 si on a mentionné moins que les 5 mesures essentielles.
K18	Prééclampsie sévère confirmée, quelle est la conduite ? Cocher les réponses spontanées (Autoriser les réponses multiples) (Demander s'il y a autre chose)	⌋ 1. Admettre en hospitalisation et assurer le confort au lit ⌋ 2. Communiquer à la famille tous les aspects de la prise en charge ⌋ 3. Administrer en IV lente sur 5minutres une 4g de la solution 20% sulfate magnésium ⌋ 4. Continuer immédiatement avec injection IM de 5g d'une solution de 50% magnésium sulfate dans chaque fesse, en y ajoutant de la lidocaïne 2% ; 1 ml dans Ia même seringue ⌋ 5. Après 4 heures, poursuivre avec la dose d'entretien : injection IM de 5g de solution 50% de magnésium sulfate, mélangé avec de la lidocaïnes 2%, 1ml dans la même seringue. Toutes les 4h, c'est une injection alternative dans chaque fesse ⌋ 6. Continuer le traitement avec sulfate de magnésium pour une durée de 24 h après accouchement ou le dernier épisode de convulsion ⌋ 7. Autres: (spécifier)	Mesures essentielles Si les variables 1, 2, 3,4, 5 et 6 sont toutes mentionnées, inscrire 1 dans la case. Inscrire 0 si on a mentionné moins que les 6 mesures essentielles.

K19	Avant d'administrer la dose d'entretien du sulfate de magnésium, des précautions particulières doivent être observées. Pouvez-vous nous en dire plus ? Cocher les réponses spontanées (Autoriser les réponses multiples) (Demander s'il y a autre chose)	⌋ 1. Rythme respiratoire d'au moins 16 cycles par minute ⌋ 2. Reflexes patellaire présents ⌋ 3. Diurèse d'au moins 30ml/h pour plus 4 heures ⌋ 4. Autres (spécifier):	Mesures essentielles Si les variables 1, 2, et 3 sont toutes mentionnées, inscrire 1 dans la case. Inscrire 0 si on a mentionné moins que les 3 mesures essentielles. ⌋
K20	En cas d'arrêt cardiaque lié à l'administration du sulfate de magnésium, quelle est la conduite ? Cocher les réponses spontanées (Autoriser les réponses multiples) (Demander s'il y a autre chose)	⌋ 1. Ventilation assistée ⌋ 2. Donner Gluconate de Calcium1g (ou 10ml d'une solution 10%) IV lente jusqu'à ce que la respiration antagonise les effets du magnésium sulfate ⌋ 3. Autres (spécifier):	Mesures essentielles Si les variables 1, 2, et 3 sont toutes mentionnées, inscrire 1 dans la case. Inscrire 0 si on a mentionné moins que les 3 mesures essentielles. ⌋
K21	Quels sont les principaux éléments de surveillance dans la prise en charge d'une prééclampsie sévère Cocher les réponses spontanées (Autoriser les réponses multiples) (Demander s'il y a autre chose)	⌋ 1. Voie veineuse et perfusion de solutés ⌋ 2. Fiche de surveillance des entrées/sortie pour éviter les surcharges hydriques ⌋ 3. Surveiller la survenue des signes de surcharge comme OAP ⌋ 4. Sondage vésicale pour surveiller la diurèse et mesurer la protéinurie ⌋ 5. Surveiller signes vitaux, reflexes et BCF toutes les heures ⌋ 6. Evaluer le niveau de coagulation pour éliminer des troubles de coagulation ⌋ 7. Autres (spécifier):	Mesures essentielles Si les variables 1, 2, 3, 4, 5 et 6 sont toutes mentionnées, inscrire 1 dans la case. Inscrire 0 si on a mentionné moins que les 6 mesures essentielles. ⌋
Newborn care			
K22	Après l'accouchement, quels sont les soins immédiats au nouveau-né ? Cocher les réponses spontanées (Autoriser les réponses multiples) (Demander s'il y a autre chose)	⌋ 1. A la naissance, essuyer la face, nez, et la bouche ⌋ 2. Soins du cordon (section aseptique 4 – 6 cm de l'ombilic) ⌋ 3. S'assurer que le nouveau-né respire ⌋ 4. Protection thermique ⌋ 5. Initier l'allaitement dans la première heure ⌋ 6. Examen du nouveau-né dans la première heure ⌋ 7. Peser le bébé ⌋ 8. Prophylaxie oculaire ⌋ 9. Autres: (spécifier)	Mesures essentielles Si les variables 1, 2, 3, 4, 5, 6, 7, et 8 sont toutes mentionnées, inscrire 1 dans la case. Inscrire 0 si on a mentionné moins que les 8 mesures essentielles. ⌋
K23	Si un nouveau-né ne respire pas dès la naissance, que feriez-vous? Cocher les réponses spontanées (Autoriser les réponses multiples)	1. Éliminer des voies aériennes le sang et le mucus 2. Sécher et envelopper le bébé dans un linge chaud et propre 3. Placer sous une source de chaleur rayonnante 4.Assister la respiration à l'aide d'un sac Ambu 5. Faire un massage cardiaque 6. Faire une succion s'il y a méconium	Mesures essentielles Si les variables 1, 2, 3, 4, 5, et 6 sont toutes mentionnées, inscrire 1 dans la case. Inscrire 0 si on a mentionné moins que les 6 mesures essentielles. ⌋
Formation reçues			

K24	Avez-vous appris au collège ou par votre expérience ou au cours de la formation médicale/continue ou la formation en cours d'emploi de quelle façon : Lire la liste à haute voix et cocher la case en cas de réponse affirmative	1. Fournir des soins prénataux ciblés 2. Utiliser les partogrammes pour gérer le travail 3. Extraction manuelle du placenta 4. Perfusion par IV 5. Prise du rythme cardiaque 6.Administrer du MgSO4 pour gérer l'éclampsie ou la prééclampsie 7. Réanimation des adultes/nouveau-nés 8. Dépistage du cancer du col 9. Compression bimanuelle de l'utérus (externe) 10. Compression bimanuelle de l'utérus (interne) 11. Suture des épisiotomies (réparation) 12. Suture des lacérations vaginales 13. Suture des lacérations cervicales 14. Suture des lacérations de 3e ou 4e degré
K25	Avez-vous utilisé ces techniques au cours des trois derniers mois ? Lire à haute voix et cocher les réponses affirmatives	1. Soins prénataux ciblés 2. Utilisation des partogrammes pour suivre le travail 3. Enlèvement manuel du placenta 4. Mise en place de perfusions IV 5.Vérification du rythme cardiaque 6.Administration de MgSO4 pour la gestion de l'éclampsie/ prééclampsie 7. Compression bimanuelle de l'utérus (externe) 8. Compression bimanuelle de l'utérus (interne) 9. Suture des épisiotomies (réparation) 10. Suture des lacérations vaginales 11. Suture des lacérations cervicales 12. Suture des lacérations de 3e ou 4e degré 13. Utilisation de la ventouse obstétricale 14.Aspiration manuelle intra-utérine 15.Autre (préciser):

Supplemental material 10. Revision of the study tools by the technical committee

REPUBLIQUE DU BURUNDI

Bujumbura, le ..07../06/2022

MINISTERE DE LA SANTE PUBLIQUE
ET DE LA LUTTE CONTRE LE SIDA
SECRETARIAT PERMANENT

A Docteur, Madame/Monsieur
.....

N° Réf. 307/...SP..../SP/2022

Objet : Invitation

Madame/Monsieur.....,

Le Ministère de la Santé Publique et de la Lutte contre le SIDA, à travers son Programme National de Santé de la Reproduction compte réaliser l'enquête SONU pour évaluer le niveau de fonctionnement du réseau SONU du Burundi. Il est prévu un atelier de révision du protocole et des outils de collecte des données par le comité technique qui se tiendra à Ngozi **en dates du 13 au 15 juin 2022 à partir de 8h00.**

Par la présente, je voudrais vous inviter à venir participer dans cet atelier.

Veuillez agréer, Docteur/Madame/Monsieur....., l'assurance de ma considération distinguée.

LE SECRETAIRE PERMANENT AU MSPLS

ET PRESIDENT DU COMITE DE PILOTAGE DE L'ENQUETE SONU AU BURUNDI

Dr Jean Baptiste NZORIRONKANKUZE

07/6/2022

Supplemental material 11. Validation of the study tools by the steering committee

REPUBLIQUE DU BURUNDI

Bujumbura, le ..07./06/2022

MINISTERE DE LA SANTE PUBLIQUE
ET DE LA LUTTE CONTRE LE SIDA
SECRETARIAT PERMANENT

A Monsieur le Représentant résident
.....

N° Réf. :305/...SP..../SP/2022

Objet : Demande d'une personne ressource

Monsieur le Représentant,

Le Ministère de la Santé Publique et de la Lutte contre le SIDA, à travers son Programme National de Santé de la Reproduction compte réaliser l'enquête SONU pour évaluer le niveau de fonctionnement du réseau SONU du Burundi. Il est prévu un atelier de validation du protocole et des outils de collecte des données par le comité de pilotage qui se tiendra à Bujumbura **en date du 16 juin 2022 à partir de 8h00.**

Par la présente, je voudrais vous demander de bien vouloir autoriser le responsable de la santé de la reproduction dans votre institution à venir appuyer cet atelier.

Veuillez agréer, Monsieur le Représentant, l'assurance de ma considération distinguée.

LE SECRETAIRE PERMANENT AU MSPLS

ET PRESIDENT DU COMITE DE PILOTAGE DE L'ENQUETE SONU AU BURUNDI

Dr Jean Baptiste NZORIRONKANKUZE

07/6/2022

Supplemental material 12. Actual budget for onsite EmONC training (2025)

RENFORCEMENT DES CAPACITES DES PRESTATAIRES EN SONU IN SITU SELON L'APPROCHE MENTORAT DANS UN SITE

Libellé de l'activité	Nombre	Nbre jours	Fréquence	Qé totale	CU en BIF	CT en BIF
Honoraires pour le mentor spécialiste/site pendant 45 jours (gynecologue)	3	45	1	135	342,797	46,277,595
Honoraires pour les mentors spécialistes/site pendant 30 jours (pédiatre, Médecin spécialiste anesthésiste réanimateur)	6	30	1	180	342,797	61,703,460
Perdiem pour les 2 mentors pour 45 jours (gynécologue et sage femme)	6	45	1	270	150,000	40,500,000
Perdiem pour les 2 mentors pour 30 jours (pédiatre et Médecin anesthésiste réanimateur)	6	30	1	180	150,000	27,000,000
Perdiem pour les 15 médecins mentorés pendant 45 jours	45	45	1	2025	150,000	303,750,000
Perdiem pour les 15 infirmiers anesthésistes pendant 30 jours	45	30	1	1350	150,000	202,500,000
Ticket aller-retour pour 15 Médecins mentorés et 15 infirmiers anesthésistes	90	1	1	90	64,000	5,760,000
Ticket aller-retour pour 1 sage-femme rotation après 15 jours	9	1	1	9	64,000	576,000
Ticket aller-retour pour 1 infirmier anesthésiste rotation après 15 jours	6	1	1	6	64,000	384,000
Location d'un véhicule pour le déplacement d'un gynécologue,pédiatre,Médecin anethésiste réanimateur: 1 véhicule par aller/retour après deux semaines ,4 tours (un tour tous les 15 jours)	3	4	1	12	680,000	8,160,000
Carburant d'un véhicule pour le déplacement d'un gynécologue,pédiatre,Médecin anethésiste réanimateur: 1 véhicule par aller/retour après deux semaines ,4 tours (un tour tous les 15 jours) 60L par tour	180	4	1	720	4,000	2,880,000
Perdiem de l'équipe de supervision de l'activité 3 cadres du PNSR (PC, S&E, Service Gestion): 3 nuités tous les 15 jours pendant 45 jours (au debut , au milieu et à la fin)	9	3	3	81	150,000	12,150,000
Perdiem de l'équipe de coordination de l'activité par un cadre de la direction du PNSR : 1 nuitée au début et à la fin des 45 jours	6	1	1	6	150,000	900,000
Perdiem du chauffeur du cadre de la direction du PNSR : 1 nuitée au début et à la fin des 45 jours (au début et à la fin)	6	1	1	6	150,000	900,000
Carburant de 1 véhicule de la direction du PNSR pour la coordination de l'activité: - aller-retour: 50L, 2 fois	50	3	2	300	4,000	1,200,000
Cout total						**714,641,055**

Source: National Programme on Reproductive, Maternal, Newborn, Child, and Adolescent Health (RMNCAH), Republic of Burundi (May 2025)

Supplemental material 13. Actual EmONC monitoring budget (2025)

BUDGET OPERATIONNEL DU MONITORING SONU

1. Formation des évaluateurs

Libellé	Unité	Qté	Nbre de Jrs	PU	PT
1. Perdiem + Frais de déplacement des participants + Frais de présentation et organisation					6,250,500
Perdiem des enquêteurs (non locaux)	pers	21	1	182,500	3,832,500
Frais de déplacement des enquêteurs et superviseurs locaux	pers	26	1	19,000	494,000
Frais de déplacement des enquêteurs du niveau opérationnel	pers	21	1	64,000	1,344,000
Frais de communication pour l'invitation des participants	Carte	3	1	10,000	30,000
Frais de présentation	pers	3	1	150,000	450,000
Frais d'organisation	pers	1	1	100,000	100,000
2.Autres frais					3,535,400
Location salle	Salle	1	1	330,000	330,000
Pause-café	Pers	47	1	22,000	1,034,000
Pause-déjeuner	Pers	47	1	44,000	2,068,000
Eau minérale dans la salle	Pers	47	1	2,200	103,400
Total 1: Formation des évaluateurs					**9,785,900**

2. Collecte des données sur terrain

2.1. Per diem et prime					148,118,000
Perdiem des enquêteurs et superviseurs	Pers	47	5	150000	35,250,000
Prime d'Enquêteurs pour 42 agents de collecte des données	Pers	42	4	126,000	21,168,000
Prime de 5 superviseurs	Pers	5	4	165,000	3,300,000
Location véhicule pour les agents de collecte des données et superviseurs avec carburant	Véh	26	5	680,000	88,400,000
2.2. Autres frais					1,870,000
Crédit de téléphone pour 42 enquêteurs et 5 superviseurs	Pers	47	1	10,000	470,000
Carburant pour 3 véhicules de direction pour la coordination	Véh	3	90	4,000	1,080,000
Multiplication des fiches de collecte de données	pièce	160	1	2000	320,000
Total 2 : Collecte des données sur terrain					**149,988,000**
Libellé	**Unité**	**Qté**	**# jrs**	**CU**	**CT**
1. Perdiem et frais de présentation					8,750,000

Per diem des participants 1ère nuitée	pers	10	1	150,000	1,500,000
Per diem des participants Autres nuitées	pers	10	5	132,000	6,600,000
Frais de présentation	pers	3	1	150,000	450,000
Frais d'organisation et de rapportage	pers	2	1	100,000	200,000
2.Autres frais					14,440,000
Location salle	Salle	1	5	200,000	1,000,000
Pause-café	Pers	10	5	22,000	1,100,000
Pause-déjeuner	Pers	10	5	44,000	2,200,000
Eau minérale dans la salle	Pers	20	5	2,200	220,000
Location du véhicule	pers	2	7	680,000	9,520,000
Carburant pour 2 véhicules de direction	Véh	2	50	4,000	400,000
Total 3 : Analyse des données et production					**23,190,000**

4. Atelier d'élaboration du rapport Monitoring SONU

Libellé	**Unité**	**Qté**	**# jrs**	**CU**	**CT**
1. Perdiem et frais de présentation					8,650,000
Perdiem des participants 1ère nuitée	pers	10	1	150,000	1,500,000
Perdiem des participants Autres nuitées	pers	10	5	132,000	6,600,000
Frais de présentation	pers	3	1	150,000	450,000
Frais d'organisation	pers	1	1	100,000	100,000
2.Autres frais					14,520,000
Location salle	Salle	1	5	200,000	1,000,000
Pause-café	Pers	10	5	22,000	1,100,000
Pause-déjeuner	Pers	10	5	44,000	2,200,000
Eau minérale dans la salle	Pers	20	5	2,200	220,000
Location du véhicule	pers	2	7	680,000	9,520,000
Carburant pour 2 véhicules de direction	Véh	2	60	4,000	480,000
Total 3 : Analyse des données et production du rapport					**23,170,000**

4. Atelier de restitution des résultats du monitoring SONU

BUHUMUZA

Rubrique	**Unité**	**Qté**	**# nuitées**	**CU**	**CT**
Per diem de 12 participants du niveau central (3 Cabinet du Ministre, 1 DSNIS, 7 PNSR, DGSSLS: 1) 1ère nuitée	pers	12	1	150,000	1,800,000
Per diem de 12 participants du niveau central (3 Cabinet du Ministre, 1 DSNIS, 7 PNSR, DGSSLS: 1) 2ème nuitée	pers	12	1	132,000	1,584,000

Per diem des participants non locaux en provenance des provinces (3 MDPS + 9 MCD + 13 MDH + 12 SONUB)	pers	37	1	150,000	5,550,000
Per diem pour 3 chauffeurs de direction 1ère nuitée	pers	3	1	150,000	450,000
Per diem pour 3 chauffeurs de direction 2ème nuitée	pers	3	1	132,000	396,000
Ticket aller-retour des participants non locaux	pers	37	1	64,000	2,368,000
Partenaires	pers	6	1	- 0	- 0
Frais de présentation	pers	3	1	150,000	450,000
Frais de rapportage	pers	1	1	100,000	100,000
Frais de communication pour l'invitation des participants	carte	3	1	10,000	30,000
Sous total 1					**12,728,000**
Logistique et autres besoins					
Location salle	salle	1	1	330,000	330,000
Pause-café	pers	71	1	22,000	1,562,000
Pause-déjeuner	pers	71	1	44,000	3,124,000
Eau minérale	pers	142	1	2,200	312,400
Stylos	Piece	55	1	1,200	66,000
Bloc-notes	Piece	55	1	3,200	176,000
Location véhicules pour les cadres du niveau central	Véh	3	7	680,000	14,280,000
Carburant pour véhicule de direction	Véh	180	1	4,000	720,000
Sous total 2					20,570,400
TOTAL BUHUMUZA					**33,298,400**

BUJUMBURA

Rubrique	**Unité**	**Qté**	**# nuitées**	**CU**	**CT**
Per diem de 12 participants du niveau central (3 Cabinet du Ministre, 1 DSNIS, 7 PNSR, DGSSLS: 1) 1ère nuitée	pers	12	0	150,000	- 0
Per diem de 12 participants du niveau central (3 Cabinet du Ministre, 1 DSNIS, 7 PNSR, DGSSLS: 1) 2ème nuitée	pers	12	1	132,000	1,584,000
Per diem des participants non locaux en provenance des provinces (6 MDPS + 15 MCD + 25 MDH + 9 SONUB)	pers	55	1	150,000	8,250,000
Per diem pour 3 chauffeurs de direction 1ère nuitée	pers	3	0	150,000	- 0
Per diem pour 3 chauffeurs de direction 2ème nuitée	pers	3	1	132,000	396,000
Ticket aller-retour des participants non locaux	pers	55	1	64,000	3,520,000
Partenaires	pers	4	1	- 0	- 0
Frais de présentation	pers	3	1	150,000	450,000
Frais de rapportage	pers	1	1	100,000	100,000

Frais de communication pour l'invitation des participants	carte	3	1	10,000	30,000
Sous total 1					**14,330,000**
Logistique et autres besoins					
Location salle	salle	1	1	330,000	330,000
Pause-café	pers	74	1	22,000	1,628,000
Pause-déjeuner	pers	74	1	44,000	3,256,000
Eau minérale	pers	148	1	2,200	325,600
Stylos	Piece	55	1	1,200	66,000
Bloc-notes	Piece	55	1	3,200	176,000
Sous total 2					5,781,600
TOTAL BUJUMBURA					**20,111,600**

BURUNGA

Rubrique	**Unité**	**Qté**	**# nuitées**	**CU**	**CT**
Per diem de 12 participants du niveau central (3 Cabinet du Ministre, 1 DSNIS, 7 PNSR, DGSSLS: 1) 1ère nuitée	pers	12	0	150,000	- 0
Per diem de 12 participants du niveau central (3 Cabinet du Ministre, 1 DSNIS, 7 PNSR, DGSSLS: 1) 2ème nuitée	pers	12	1	132,000	1,584,000
Per diem des participants non locaux en provenance des provinces (4 MDPS + 9 MCD + 19 MDH + 7 SONUB)	pers	39	1	150,000	5,850,000
Per diem pour 3 chauffeurs de direction 1ère nuitée	pers	3	0	150,000	- 0
Per diem pour 3 chauffeurs de direction 2ème nuitée	pers	3	1	132,000	396,000
Ticket aller-retour des participants non locaux	pers	39	1	64,000	2,496,000
Partenaires	pers	6	1	- 0	- 0
Frais de présentation	pers	3	1	150,000	450,000
Frais de rapportage	pers	1	1	100,000	100,000
Frais de communication pour l'invitation des participants	carte	3	1	10,000	30,000
Sous total 1					**10,906,000**
Logistique et autres besoins					
Location salle	salle	1	1	330,000	330,000
Pause-café	pers	60	1	22,000	1,320,000
Pause-déjeuner	pers	60	1	44,000	2,640,000
Eau minérale	pers	120	1	2,200	264,000
Stylos	Piece	39	1	1,200	46,800
Bloc-notes	Piece	39	1	3,200	124,800
Sous total 2					4,725,600

TOTAL BURUNGA					**15,631,600**
BUTANYERERA					
Rubrique	**Unité**	**Qté**	**# nuitées**	**CU**	**CT**
Per diem de 12 participants du niveau central (3 Cabinet du Ministre, 1 DSNIS, 7 PNSR, DGSSLS: 1) 1ère nuitée	pers	12	0	150,000	- 0
Per diem de 12 participants du niveau central (3 Cabinet du Ministre, 1 DSNIS, 7 PNSR, DGSSLS: 1) 2ème nuitée	pers	12	1	132,000	1,584,000
Per diem des participants non locaux en provenance des provinces (3 MDPS + 10 MCD + 16 MDH + 9 SONUB)	pers	38	1	150,000	5,700,000
Per diem pour 3 chauffeurs de direction 1ère nuitée	pers	3	0	150,000	- 0
Per diem pour 3 chauffeurs de direction 2ème nuitée	pers	3	1	132,000	396,000
Ticket aller-retour des participants non locaux	pers	38	1	64,000	2,432,000
Partenaires	pers	6	1	- 0	- 0
Frais de présentation	pers	3	1	150,000	450,000
Frais de rapportage	pers	1	1	100,000	100,000
Frais de communication pour l'invitation des participants	carte	3	1	10,000	30,000
Sous total 1					**10,692,000**
Logistique et autres besoins					
Location salle	salle	1	1	330,000	330,000
Pause-café	pers	59	1	22,000	1,298,000
Pause-déjeuner	pers	59	1	44,000	2,596,000
Eau minérale	pers	118	1	2,200	259,600
Stylos	Piece	38	1	1,200	45,600
Bloc-notes	Piece	38	1	3,200	121,600
Sous total 2					4,650,800
TOTAL BUTANYERERA					**15,342,800**
GITEGA					
Rubrique	**Unité**	**Qté**	**# nuitées**	**CU**	**CT**
Per diem de 12 participants du niveau central (3 Cabinet du Ministre, 1 DSNIS, 7 PNSR, DGSSLS: 1) 1ère nuitée	pers	12	0	150,000	- 0
Per diem de 12 participants du niveau central (3 Cabinet du Ministre, 1 DSNIS, 7 PNSR, DGSSLS: 1) 2ème nuitée	pers	12	0	132,000	- 0
Per diem des participants non locaux en provenance des provinces (2 MDPS + 6 MCD + 15 MDH + 12 SONUB)	pers	35	1	150,000	5,250,000
Per diem pour 3 chauffeurs de direction 1ère nuitée	pers	3	0	150,000	- 0

Per diem pour 3 chauffeurs de direction 2ème nuitée	pers	3	1	132,000	396,000
Ticket aller-retour des participants non locaux	pers	35	1	64,000	2,240,000
Partenaires	pers	6	1	- 0	- 0
Frais de présentation	pers	3	1	150,000	450,000
Frais de rapportage	pers	1	1	100,000	100,000
Frais de communication pour l'invitation des participants	carte	3	1	10,000	30,000
Sous total 1					**8,466,000**
Logistique et autres besoins					
Location salle	salle	1	1	330,000	330,000
Pause-café	pers	56	1	22,000	1,232,000
Pause-déjeuner	pers	56	1	44,000	2,464,000
Eau minérale	pers	112	1	2,200	246,400
Stylos	Piece	35	1	1,200	42,000
Bloc-notes	Piece	35	1	3,200	112,000
Sous total 2					4,426,400
TOTAL GITEGA					**12,892,400**
TOTAL RESTITUTION					**97,276,800**
TOTAL GENERAL					**303,410,700**

Source: National Programme on Reproductive, Maternal, Newborn, Child, and Adolescent Health (RMNCAH), Republic of Burundi (May 2025)

Supplemental material 14. Prediction of workforce (midwives) impact on MMR reduction

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**				
Total worker surplus					**20**	***Probabilities***	**8.86**	**7.02**	**10.69**

Supplemental material 14 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 6.1). 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.